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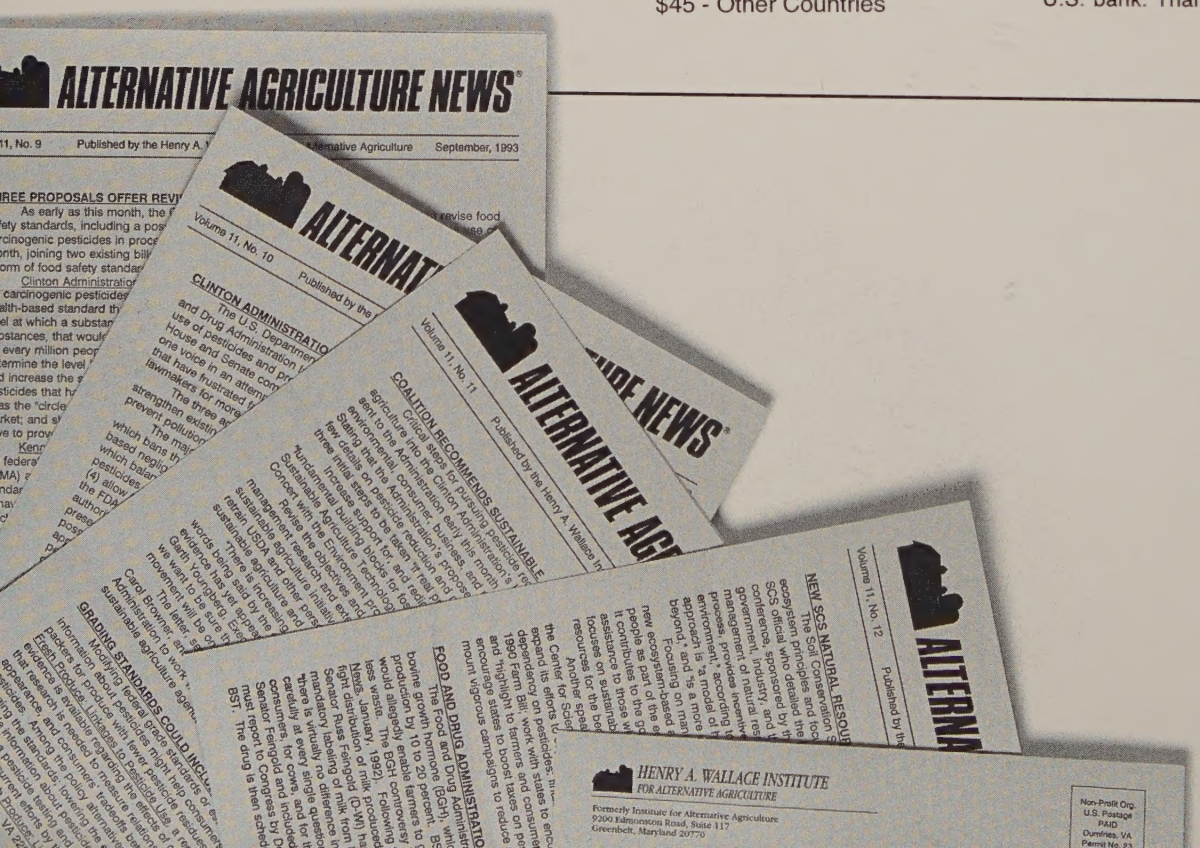

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The cover shows the traditional Indian method of weed control by intercultivating with blade harrows in a broadcast-seeded field. Photo provided by K.P.R. Vittal, Central Research Institute for Dryland Agriculture, Santoshnagar, India.

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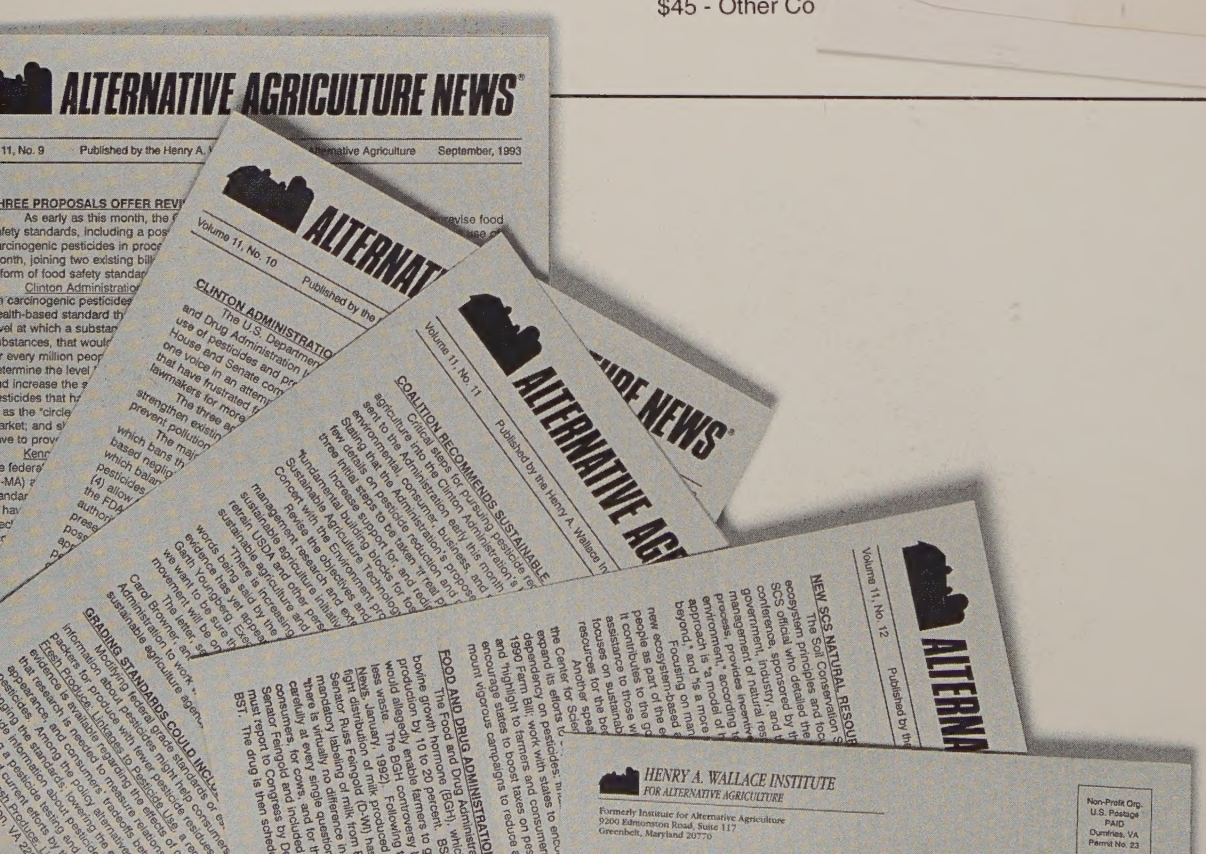

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Soil and water conservation and improved crop management effects on watershed productivity in Andhra Pradesh, India

K.P.R. Vittal, S.K. Das, J.C. Katyal, N. Munikrishnaiah, and M. Rajender Reddy

Abstract. *Soil and water conservation and improved crop management programs were initiated in 1983 to increase the productivity of a dryland vertisol watershed in the state of Andhra Pradesh in the semi-arid tropical region of India. This was one of 47 model watersheds developed by the Government of India. The integrated program consisted of measures to conserve soil and water, such as a percolation tank, grading, checks, and deep tillage, on which were superimposed improved crop management practices (e.g., cultivars, fertilizers, and timeliness in operations), carried out with the farmers' cooperation and partial payment. All participants were surveyed in 1983, before starting the program, and 1988, after completing the program. The equilibrium water levels in open wells increased about 50 cm, which allowed sugarcane to be introduced. About 10% additional area was reclaimed and cultivated after construction of a diversion dam. Fodder supply improved because of the growth of natural grasses on terraces formed by stone checks in waterways. Soil and water conservation efforts reduced runoff about 26%. Ground cover increased by 38% because of increased cropping intensity, and income per capita grew by 67% per year. Thus, the integrated approach conserved natural resources and improved productivity.*

Key words: community participation, on-farm research, watershed, vertisols

Historical Perspective

In the past, progress in improving the productivity of dryland agriculture was hindered by the unavailability of improved cultivars responsive to a package of management practices including: contour bunding; deep tillage once in three years; addition of farm yard manure (FYM) once in three years; wider crop rows and lower seeding rates; inter-row cultivation for weed control; mixed cropping; and crop rotations (Kanitkar et al., 1960; Singh, 1987). According to official estimates, adoption of this package of practices increased yields of cereals, pulses and edible oilseeds by 15 to 20% over the base yields of 200 to 400 kg/ha (ICAR, 1976). However, the farmers regarded contour embankments of 1.5 to 3.0 m^2 cross-sectional area as impediments (Kanitkar et al., 1960), and upkeep of soil conservation structures was poor (Government of Punjab, 1987). These mechanical barriers impounded water but did not recharge the inter-bund area uniformly (Cogle and Rao, 1994). Impounding next to the bund was due to the predominantly 2:1 type of clay with low infiltration rates. Farmers often breached the embankments to let out the water to make planting easier, thereby damaging fields downstream. Thus, the farmers found the package of practices unattractive.

In 1983, the Indian Council of Agricultural Research (ICAR) recognized the seriousness of the problem and initiated a program of model watersheds addressing site-specific problems in 47 locations representing different agroecological zones. These were developed as on-farm models to demonstrate proven dryland technology to increase productivity throughout a watershed. Both soil conservation and crop management were needed to attract farmers' attention (Saliba, 1985). It was difficult to demonstrate and extend soil and water conservation principles and obtain community participation (Moldenhauer and Hudson, 1988). Structural support reinforced by training and education was needed for soil conservation (Ooster and Cahill, 1986). Therefore, government action was recommended to plan and coordinate the developmental research (Sivanappan and Panchanathan, 1985). The model watershed program, which was partially financed by government, included new varieties and hybrids of cereals, oilseeds and other crops, and an integrated package of high-yielding practices superimposed on suitable, effective soil and water conservation measures that increased productivity and income. This article describes the status of production before and after the program was instituted, and the structural changes that occurred in conservation measures. It covers the period 1983 to 1993 in a vertisol model watershed in the semi-arid tropics of India.

K.P.R. Vittal is Senior Scientist (Soil Science), S.K. Das is Project Coordinator (Research), J.C. Katyal is Director, N. Munikrishnaiah is Technical Officer (Soil and Water Conservation) and M. Rajender Reddy is Technical Officer (Soil Science), Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad 500059, Andhra Pradesh, India.

Planning the Intervention

Research in India in the last two decades had laid the foundation for increasing and sustaining the productivity of dryland agriculture through timeliness of operations, improved cultivars, fertilizer application, and soil and water conservation (CRIDA, 1988). This technology is superior to traditional technology recommended for various agroclimatic conditions. The information compiled over many seasons and in many places was adapted for practical field intervention, achieving a substantial breakthrough in yields of locally grown crops at one model watershed located 115 km from Hyderabad, on the western border of Andhra Pradesh state.

The watershed has an area of 673 ha. It is at an altitude of 512 m, at longitude 17′38°N and latitude 78′05°E in Chevella-Pothulboguda villages, Medak district, Andhra Pradesh (Fig. 1). Land capability classes I, IIe, IIes, and IV occupy areas of 9, 532, 114, and 18 ha, respectively. The major soil orders are entisol (10 ha), inceptisol (123 ha), vertic inceptisol (123 ha) and pellustert (417 ha). The mean rainfall is 871 mm. Of the 338 farmers in the watershed, 182 have less than 1 ha of land.

Local meetings were held in the twin villages of Chevella-Pothulboguda. Implementation of earlier work in local soil conservation has been slow, and many discussions were needed to convince the farmers of the soundness of new approaches, which they accepted hesitantly. The team members lived in the villages, and some enterprising youths were involved in day-to-day activities. Surveys and selection of the sites for checks, dams and drains were carried out with the cooperation of the farmers. This made a radical difference compared with the earlier approach of imposing solutions without considering farmers' perspectives of their problems and their preferred ways to deal with them. A survey was made of the farmers and their problems. Farmers gave higher priority to crop management than to soil and water conservation. The details of intervention in these two areas are covered in the following section.

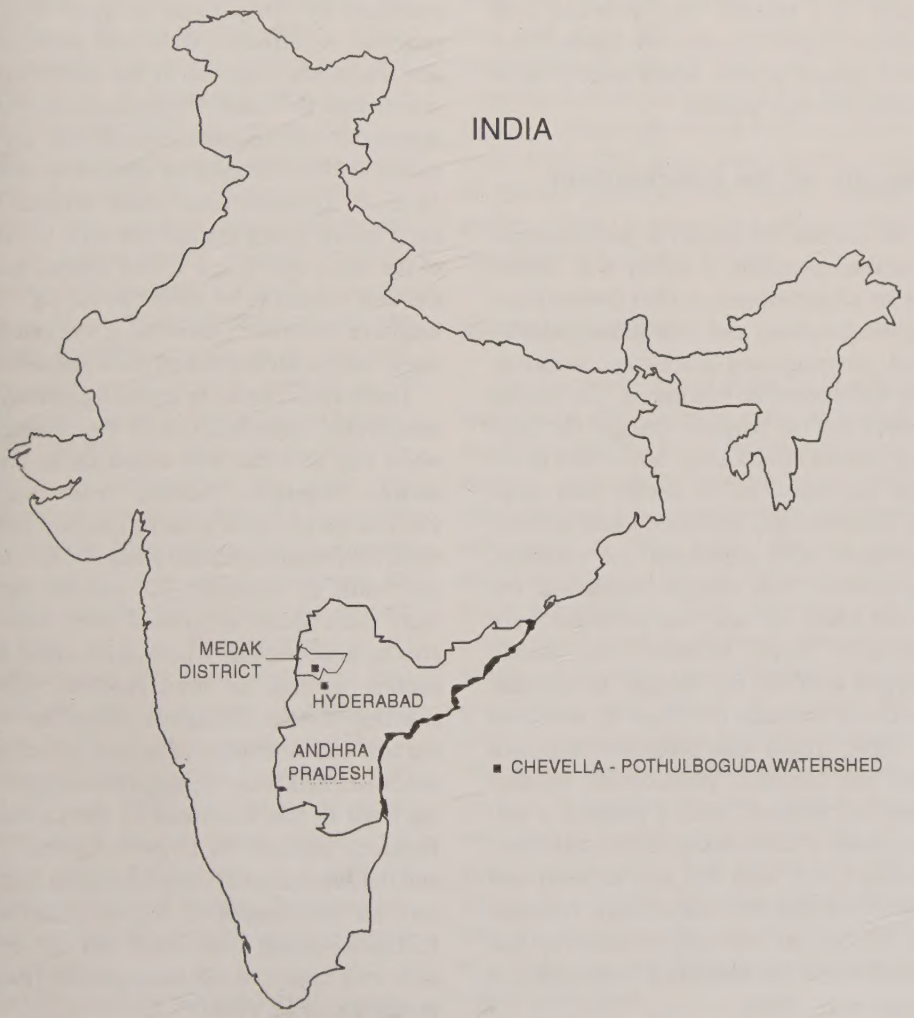

Figure 1. Location of the Chevella-Pothulboguda model watershed.

Measures Taken

Soil and water conservation

Soil erosion was a problem in 22% of the area, but drainage in only 8%. There were two gullies with a total length of 10 km. The entire runoff originating inside the watershed drained externally. To receive part of the runoff from the watershed, an old percolation tank of 8 ha-m capacity needed to be renovated (this is an aboveground water storage structure constructed across streamlets exclusively for recharging ground water). A careful survey identified 10 micro watersheds. A diversion drain was designed to divert water to the percolation tank. Small gullies were treated and restored to control soil erosion. A main waterway was developed, along with appropriate engineering structures from locally available boulders. These structures were fortified by a grass, *Cenchrus ciliaris*, and *Kalabanda* (*Agave* sp.) that are native to the site. These were supplemented with brushwood obstructions. The brushwood was collected from locally grown unbrowsable material; it was driven into the ground and was held firmly by wooden spikes. This made a great difference in directing excess water to its predetermined course.

Soil and water conservation works on individual farmer's fields were conducted with a 25% subsidy, whereas community development works were entirely at government expense. The percolation tank was rejuvenated by digging a 0.8-km feeder channel. Gullies were stabilized by shaping their walls and providing boulders or gabions for beds, and chute outlets. Surfaces were graded (0.2–0.6%) with bunds 0.54-m^2 in cross-section. At a vertical interval of 1.0 m on a 1.7% slope, these graded bunds reduced the velocity of the water to less than 0.35 m/s and they could withstand a rainfall intensity of about 56 mm/h, which is expected once in two years. The bunds are earthen structures constructed in areas of

medium to high rainfall across the major slope with a small gradient for draining excess water. Weirs were built with stones to withstand the same rainfall intensity and a discharge rate of 0.7 m^3/sec. Weirs 2 m long by 0.45 m high, called "waste weirs," were built to handle the excess runoff from the graded bunds. Grassed waterways were provided for safe disposal of the runoff arising from the bunded areas through the waste weirs. Stone checks were installed in the waterways at a vertical interval of 0.5 m to stop the bed from eroding. Depending on the characteristics of the particular location, vetiver (*Vetiveria zizanoides*) and agave (*Agave americana*) were planted as checks in place of stone checks to reduce cost. Checks were also constructed with available brush from the fields. To conserve moisture between the terraces, the soil was deep tilled with a tractor.

Crop husbandry measures

Although the program tackled the problem of erosion by water, its immediate impact was on crop husbandry. Most farmers used low yielding local cultivars (89%), applied less than half the recommended application rate of fertilizers (83%), did nothing to manage weeds (100%), and made little use of pesticides (2%). The program substituted new and improved crops and varieties for local cultivars that had been used for a long time. Crop production practices recommended for the watershed were based on research results. Seeds, fertilizer and pesticides were provided to farmers at 25% subsidy.

The crops were sorghum (*Sorghum bicolor* [L.] Moench cv. 'CSH 5'), greengram (*Vigna radiata* [L.] Wilczek cv. 'PS 16'), blackgram (*Vigna mungo* [L.] Hepper cv. 'T 9'), sunflower (*Helianthus annuus* L. cv. 'Morden'), pigeonpea (*Cajanus cajan* [L.] Millsp. cv. 'BDN 2') and safflower (*Carthamus tinctorius* L. cv. 'Manjira'). A basal banding of 10 kg/ha N and 13 kg/ha P was applied as diammonium phosphate for all crops. Cereal and oilseed crops received an additional 30 kg/ha N as a split band in the fourth week after planting. Post-monsoon crops (sorghum and safflower) received full doses of fertilizer through basal banding. Bullock drawn 3-row iron seed-and-fertilizer drills were provided for planting with the onset of the monsoon. This allowed faster planting with the available draft power than the traditional method of planting with a single furrow opener. Intercropping of sorghum + pigeonpea (2:1), blackgram + pigeonpea (4:1) and sunflower + pigeonpea (2:2) was introduced. In deep soils, double cropping included either greengram with safflower or greengram with sorghum.

Where weed control was difficult, planting in rows established its superiority compared with broadcasting of seeds. The shorter-season varieties aided by some application of starter N and P made a great impression on farmers because of the high gains in productivity. Other practices, such as optimal plant stands and better fertilization to meet the individual crop's needs, also increased production significantly.

Another noteworthy component was development of infrastructure and institutional support to provide critical inputs such as seed, fertilizer and pesticides. The local branch of a national bank provided crop loans and agreed to offer the inputs themselves instead of cash, which greatly facilitated technology transfer.

Results of the Intervention

To evaluate the impact of the integrated watershed program, a survey was carried out for all participants in 1983 (before starting the program) and 1988 (after completion), covering crop production, livestock, and socioeconomic conditions. The results showed that the program changed the cropping pattern significantly. Some land in cereals was converted to oilseed cash crops like sunflower and safflower, which were intercropped with pigeonpea and sorghum, respectively. This change lengthened the period when the soil was protected by a vegetative cover. However, the double cropped area did not change. In contrast, the use of fertilizers (N, P and K) increased by 35%. These improvements increased crop and livestock productivity, employment and income. Table 1 presents a balance sheet of achievements before the intervention (1983, with 824 mm of rain) and after (1988, with 808 mm of rain). Throughout this period, the crop productivity was higher within the watershed than outside it (Singh et al., 1989).

The following observations were made on the effect of soil and water conservation measures from 1987 to 1993. The graded bunds succeeded in controlling runoff and erosion. Appropriate modifications were made to meet the needs of landholders wherever design alterations did not result in a risk of soil erosion. These bunds, supported by diversion drains and checks, were effective in containing runoff from 60 mm of rainfall per day. The intensity of rainfall was not measured because of a lack of on-farm facilities. With 120 mm rainfall in a day (July 8, 1987), bunds were breached because of a drainage problem in the inter-bund area. Among 67 bunds surveyed, 9 were breached, with a total of 14 breaches. The average length of the breached bunds was 158±44 m, with the breaches averaging 2.7±1.6 m. In these vertisols, a bund length of 100 m may be adequate.

A 2×1×0.3-m silt trap (an excavated basin for capturing silt before runoff water enters the waste weir) was constructed upstream of the waste weir. These traps, protected by riprap stone or grass cover, provided an effective collection point for silt, which was returned to the field every year before the onset of the monsoon. The amount of soil trapped annually was estimated at 19 to 28 kg/ha for waste weirs and 53 to 257 kg/ha for check dams. Without a silt trap, the silting reached the crest height of the waste weir in one or two seasons and the weir needed to be rebuilt by raising the height of the crest. Therefore, it was essential to build a silt trap for all the waste weirs.

Brushwood checks in grassed waterways temporarily controlled one or two runoffs; when tied to stalks they lasted up to one season. Vegetative barriers made with *Vetiveria* sp. or *Agave* sp were effective only when fully established and when 60–90% of the width of waterway was covered with their thick stems at ground level. Stone checks, however, had a permanent effect in causing terraces to form. However, construction of stone checks was constrained by the cost and availability of suitable stones in the watershed area. Cooperative monitoring trials in this watershed by the Central Research Institute for Dryland Agriculture and the International Crops Research Institute for the Semi-Arid Tropics (CRIDA-ICRISAT) found that runoff was reduced 26% with improved soil management (Padmanabhan et al., 1989).

A diversion drain was built to divert the runoff originating from the hillocks that

Table 1. Effect of watershed intervention on crop production and income.

	1983 (before intervention)	1988 (after intervention)
Water recharge		
Percolation tank (ha-m)	0	8
Irrigation potential (ha)	8.9	19.9
Crop production (t)		
Cereals	148	80
Pulses	203	233
Oilseeds	25	123
Fertilizer use (t/yr)	22	38
Cropping intensity (%)	1.12	1.54
Forage production (t/yr)	—	590
Milk production (L/yr)	52,560	90,477
Employment (number)	777	950
Investment per capita (Rs/ha)[1]	655	1,257
Income per capita (Rs/ha)	1,505	4,010

[1] U.S.$1 is equivalent to approximately Rs.32

abutted flat land. This was followed by plugging gullies with stone boulders at several places. In one treated gully, a spring was created 3 m below groundlevel that yielded water at an average rate of 22 L/h from November 1987 to February 1988.

The percolation tank was the major source of groundwater recharge in the watershed. This tank was rejuvenated by digging an 810-m feeder channel from the abutting hillocks with a runoff collection area of 38 ha. With this arrangement, the average equilibrium recharge in the wells increased from 18 cm/d in 1986–87 to 77 cm/d in 1987–88, with rainfalls (June-October) of 638 and 739 mm, respectively. With the increase in recharge of the wells, the irrigated area increased from 8.9 ha in 1983 to 19.9 ha in 1988. Sugarcane (*Saccharum officinarum* L.) was voluntarily grown for the first time by the watershed's farmers in a block of 2 ha. Padmanabhan (1991) reported from the same watershed that groundnut (*Arachis hypogaea* L.) and rice (*Oryza sativa* L.) were grown on 1 ha of land by irrigating with the harvested runoff in 1989 and 1990. The irrigation water was provided by the runoff stored in a 1200-m^3 pond constructed in a gully by building a stop dam. Pepper (*Capsicum annuum*) was another irrigated crop grown in the watershed.

In 1993, a survey was conducted to evaluate the performance of the soil and water conservation structures in this watershed (Munikrishnaiah, 1993). Both the diversion drain and the feeder channel to the percolation tank were working satisfactorily. The cross-sectional area of the bunds was decreasing at an annual rate of 6.2%. Bed erosion was completely absent from the waterways. Rock-filled dams were effective only in shallow gullies (<1.5m depth). Deeper gullies suffered breaches and side-scooping, especially in the lower reaches.

Conclusions

The combined effects of graded bunding, waste weirs, the diversion drain and check dams were evident in the model vertisol watershed. After seeing how the waste weirs controlled soil loss, some farmers built them voluntarily in their fields. Bunding and waste weirs helped reduce soil loss. Soil and water conservation works increased water yield. Apart from agricultural production, as discussed earlier, conserving water in the percolation tank helped to reduce the drinking water problem during the summer. The check dams and waste weirs were important for levelling the area. Terraces were stabilized by natural grass. Before the program, the waterways were almost bare, with sparse grass growth. By building check dams and the diversion drain, about 1 ha of land in a 10-ha area was reclaimed and brought under cultivation.

The cropping pattern shifted from cereals toward more remunerative crops like oilseeds and pulses. The period during the year when the land was covered with vegetation increased by 38%. Fodder supply was increased by the grasses on terraces in waterways (200 kg/ha dry matter). Regeneration of intercropped pigeonpea after harvest also added to fodder production. Thus, the total productivity of the watershed was improved by implementing the program in its entirety; natural resources were conserved, and higher sustained dryland productivity was a significant benefit.

Possible future work in watershed-based dryland farming includes adoption of:

- grade-line farming with smooth contour lines instead of rigid mechanical barriers that do not fit into farmers' perceptions of what is ideal;
- low-cost structures, such as brushwood and stone checks, to reduce peak runoff and stabilize gullies;
- suitable shorter-season varieties that respond to management, increase yields, and encourage farmers' participation;
- diversion canals for groundwater recharge and for increasing irrigation potential;
- forage production systems to increase milk output, creating additional employment.

The data show that land held by farmers can have much higher production under new systems of farming for which the methods and results are demonstrated under farmers' stewardship. A good crop produced on a farmer's field has a great multiplier effect, leading to more rapid spread of the technology.

Acknowledgment. Effective implementation of this watershed program resulted from the combined efforts of the Directorate of Agriculture of Andhra Pradesh and the Central Research Institute for Dryland Agriculture.

References

1. Cogle, A.L., and K.P.C. Rao. 1994. Water conservation in soils of the semi-arid tropics. In S.M. Virmani, J.C. Katyal, H. Eswaran, and I.P. Abrol (eds). Stressed Ecosystems and Sustainable Agriculture. Oxford and IBH, New Delhi. pp. 241–252.
2. CRIDA. 1988. Improved Agronomic Practices for Dryland Crops in India. III Revised Edition. Central Research Institute for Dryland Agriculture, Hyderabad, India.

3. Government of Punjab. 1987. Soil and water conservation on watershed basis. An evaluation study. Cited in Soil and Fertiliser Abstracts, Commonwealth Agricultural Bureaux. 1989, 52(7):8125.
4. ICAR. 1976. Crop life saving research. Proc. Travelling Seminar, ICAR (India) - IRDC (Canada), 1972–73. Indian Council of Agricultural Research, New Delhi.
5. Kanitkar, N.V., S.S. Sirur, and D.H. Gokhale. 1960. Dryfarming in India. Indian Council of Agricultural Research, New Delhi.
6. Moldenhauer, W.C., and N.W. Hudson (eds). 1988. Conservation Farming on Steep Lands. Soil and Water Conservation Society, Ankeny, Iowa.
7. Munikrishnaiah, N. 1993. Performance evaluation of soil and water conservation structures in dryland watersheds. M.Tech. Thesis. Jawaharlal Nehru Technological Univ., Hyderabad, India.
8. Ooster, A.M. van, and E.J. Cahill. 1986. Towards integrated soil conservation. Land Use Policy 3:127–140.
9. Padmanabhan, M.V. 1991. Monitoring and evaluation of soil and water conservation practices at Chevella watershed. In CRIDA Annual Report 1990–91. Central Research Institute for Dryland Agriculture, Hyderabad, India.
10. Padmanabhan, M.V., S.B.P. Rao, K.L. Srivastava, and Sardar Singh. 1989. Evaluation of land treatments for vertisols and vertic soils. In CRIDA Annual Report 1988. Central Research Institute for Dryland Agriculture, Hyderabad, India.
11. Saliba, B.C. 1985. Comparative measures of effectiveness in farm level soil conservation. Soil Use and Management 1:106–110.
12. Singh, S.P. 1987. History of Indo-Canadian Dryland Research. Central Research Institute for Dryland Agriculture, Hyderabad, India.
13. Singh, R.P., K.P.R. Vittal, S.K. Das, and N.K. Sanghi. 1989. Watershed technology stabilizes yields in Andhra Pradesh. Indian Farming 39(9):34–36.
14. Sivanappan, R.K., and R.M. Panchanathan. 1985. Watershed based dryland farming. Land Use Policy 2:345–349.

INSTITUTE NEWS

Senator Culver Portrays Wallace as a Cerebral, Original Genius

Henry A. Wallace was a "quiet, cerebral man"—a "provocative and remarkably original mind," who, it was said, "was the only genius to have served as Secretary of Agriculture," according to Senator John C. Culver, who presented the 1996 Inaugural Henry A. Wallace Annual Lecture this spring. The speech, entitled "Seeds and Science: Henry A. Wallace on Agriculture and Human Progress," was attended by 110 people, including Supreme Court Justice Sandra Day O'Connor, Deputy Agriculture Secretary Richard Rominger, and Senator George McGovern.

Senator Culver painted a detailed and fascinating portrait of Wallace, who was befriended as a boy by George Washington Carver, led an agricultural revolution by developing hybrid seed, became President Franklin D. Roosevelt's youngest cabinet member at 44, and enacted federal agricultural programs which "remain the basic framework today."

"The depth and breadth of Wallace's intellectual interests" were extraordinary, according to Senator Culver. "Wallace was not only a geneticist and journalist, he was one of the nation's leading agricultural economists, an authority on statistics and author of the leading text on corn growing. . . . Somewhere along the line, he also found time to start the world's first—and still the world's largest and most successful—hybrid seed corn company," Pioneer Hi-Bred.

President Roosevelt referred to Wallace "as 'old man common sense,' and selected him as his vice presidential candidate in 1940 because, according to Eleanor Roosevelt, he could best carry out Roosevelt's domestic and foreign policy if something should happen to the President," Senator Culver said. As Vice President, Wallace delivered his most well-known public address, which came to be known as the "Century of the Common Man" speech, in which he "envisioned a worldwide revolution against the old order," according to Senator Culver.

If he were here today, Senator Culver said, "Wallace would be appalled and disgusted by the attack now being made on the nation's conservation programs, especially those related to agriculture. . . . We might guess that Wallace would look upon the sustainable agriculture movement with considerable affection."

The text of Senator Culver's lecture will soon be available from the Wallace Institute.

Wallace Institute Elects Officers, Installs New Members

The Wallace Institute Board of Directors has elected new officers for the coming year and installed five new members. The President, re-elected for another year, is **Dr. Anne K. Vidaver**, Chairperson, Department of Plant Pathology at the University of Nebraska-Lincoln; Vice President is **Dr. Frederick Kirschenmann**, farmer and manager, Kirschenmann Family Farms, Windsor and Medina, N.D.; Secretary is **Dr. Frederick R. Magdoff**, Professor, Department of Plant and Soil Science, University of Vermont; and Treasurer is **Dr. Cornelia Flora**, Professor of Sociology and Director, North Central Regional Center for Rural Development, Iowa State University.

The new members of the board are: **Dr. Neil V. Anderson,** Professor, Food Animal Health and Management Center, College of Veterinary Medicine, Kansas State University, Manhattan, KS; **Dr. Jill Shore Auburn,** Associate Director, Sustainable Agriculture Research and Education Program, University of California, Davis; **Jose Montenegro,** Acting Director, Rural Development Center, Salinas, CA; **Christine (Cass) A. Peterson,** farmer and owner, Flickerville Mountain Farm and Groundhog Ranch in Dott, Pennsylvania; and **Thomas N. Urban,** Senior Lecturer, Graduate School of Business Administration, Harvard University, and Chairman of the Board of Pioneer Hi-Bred International, Inc.

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Low-input, on-farm composting of high C:N ratio residues

D.B. Churchill, W.R. Horwath, L.F. Elliott, and D.M. Bilsland

Abstract. *Farm residues with high C:N ratios are difficult to use because of their low economic value and excessive volume. Composting is ideal for upgrading such residues, but was not thought possible without co-composting or lowering of the C:N ratio. We developed a low-input method to compost perennial ryegrass straw on-farm by forming windrows and turning them either zero, two, four, or six times throughout the year with a commercial, straddle-type turner. No water beyond normal rainfall and no N other than that contained in the straw was added. The volume of straw was reduced by up to 88% with four or six turns over 20 to 24 weeks. The average internal temperature of straw windrows reached a maximum of 54°C with four turns. The ability to compost these residues will help in the development of sustainable farming systems by allowing recycling of straw waste.*

Key words: low-input cropping systems, ryegrass, lignin, straw

Introduction

Maintaining soil quality and optimizing nutrient cycling are important goals in developing low-input cropping systems. Crop residues are critical for maintaining soil quality and conserving nutrients. Grass seed growers in Oregon's Willamette Valley produce one million metric tons of crop residue in the form of straw on roughly 150,000 ha of grass seed production fields (Young et al., 1993). During the 1940s, burning straw in grass seed fields maintained good yields while controlling weeds, invertebrate pests and fungal diseases. For several decades, open field burning has been a standard grass seed production practice in the region. Recently, however, public concern for the environmental consequences of open field burning led to legislation that severely restricts this practice (Mackey, 1991). Use of grass straw in the field, such as by shredding and chopping, has been investigated (Young et al., 1993), but these are unsatisfactory for some grass species. Alternative practices must be developed to maintain grass seed yields, control pests, and develop sustainable cropping systems. Low-input, on-site composting of grass seed straw and other crop residues is an attractive alternative to thermal and mechanical residue removal (Churchill et al., 1995). However, composting of organic material is thought to require a C:N ratio of 30:1 or less (Bollen, 1985; Biddlestone et al., 1987; Hammouda and Adams, 1987; Golueke, 1991). The main obstacle to composting grass residue is its low substrate quality and high C:N ratio, typically 50:1 or higher. Development of a grass straw composting system would benefit seed growers by creating both a method for straw disposal and a potentially valuable soil amendment.

Composting is a microbially mediated process that occurs in mainly aerobic thermophilic environments (Rynk, 1992). Composting of grass seed straw provides an excellent model to study the decomposition of plant materials having low substrate quality. Lignocellulose comprises over 70% of the residue by weight. The decomposition of high C:N plant residues such as perennial ryegrass (*Lolium perenne*) straw depends on the production of microbial by-products and stabilization of plant-derived substances. The final product potentially is valuable as an organic amendment that can improve soil quality. Beyond its value as a nutrient source, the benefits of adding compost to cropping systems are poorly understood. Limited studies have shown that compost can reduce crop disease and improve soil quality, suggesting that its soil improving qualities extend beyond its fertilizer value (Hornick et al., 1984; Hoitink et al., 1991).

We have studied the composting process under both field and laboratory conditions. The objective of this research was to develop on-farm, low-input composting technology. The field study was done to identify the abiotic conditions, minimum inputs, and on-site management practices needed for composting. The laboratory study, not reported here, was done to identify mechanisms regulating the composting process and related microbial activities involved in the decomposition of substrates with high C:N ratios.

Materials and Methods

Threshed perennial ryegrass straw was collected into three long windrows on August 18, 1992, using a ground-driven wheel rake (Rears Mfg. Co., Eugene, Oregon) and a farm-built tractor-mounted buck-rake. Turning of compost windrows is the only management variable available to most growers. Fields in the Willamette Valley usually remain inaccessible for portions of the winter and spring because of wet soil conditions. Timing of windrow turns was therefore based on site access and on having at least 3 weeks between consecutive turns. To determine the minimum number of turns required to produce a spreadable compost, the windrows were turned either 0, 2, 4 or 6 times throughout the rainy season.

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Donald B. Churchill is Project Leader, William R. Horwath is Research Soil Microbiologist, and Lloyd F. Elliott is Research Leader, USDA-Agricultural Research Service, National Forage Seed Production Research Center, Corvallis, OR 97331; Douglas M. Bilsland is Senior Faculty Research Assistant, Bioresource Engineering Department, Oregon State University, Corvallis, OR 97331.

Each of the three initial windrows was divided on October 20, 1992, into four windrows, corresponding to the four treatments (0, 2, 4 and 6 turns). Because the volume of straw decreased sharply during the experiment, the three windrows for each of the 2-, 4- and 6-turn treatments were combined into a single windrow on January 13 with a front-end loader; because of the mixing that occurred, this was counted as one turn. The three 0-turn windrows were not combined. The windrows were approximately 2 m high, 6 m wide, and 18 m long and were turned with a commercial straddle-type compost turner (Frontier Manufacturing Co.).

Volume reduction and decomposition of straw in the windrow treatments was measured (Churchill et al., 1995). The C:N ratio of the straw was determined by dry combustion and Kjeldahl analysis (Bremner and Mulvaney, 1982; Nelson and Sommers, 1982). The first C:N sample was taken as a composite from the initial three long windrows. Internal temperature of the windrows was measured weekly at depths of 30, 60, 90, 120, 150, and 180 cm to determine if thermophilic conditions were being established. Temperature monitoring started on November 4, 1992; the last reading was taken on June 7, 1993. Recording of rainfall accumulation started on August 18, 1992; the last recording was on June 15, 1993.

Table 1. Turning and sampling of windrows.

Date Turned	Treatments Turned[1]	Accumulated Rainfall from 8/18/92 to Turning (mm)	Sampling of 6-turn Windrow	
			Date	C:N
10/29/92	2,4,6	22	9/3/92	57
12/9/92	6	251	12/8/92	49
1/13/93[2]	2,4,6	375	2/2/93	22
3/11/93	4,6	511	3/2/93	16
4/20/93	6	685	4/6/93	15
5/17/93	4,6	760	5/4/93	16
6/15/93		887	6/7/93	16

[1] Treatments labelled according to the eventual number of turns.

[2] The three windrows from each turned treatment (but not the 0-turn treatment) were combined into one windrow each.

Results and Discussion

The greatest reduction in volume occurred when the straw was turned two or more times (Fig. 1). Most of the reduction occurred 16 to 21 weeks after the windrow was formed. At the end of the study (after 32 weeks) the final volume of the unturned windrows was significantly greater ($p<0.05$) than windrows turned 2, 4, or 6 times. The C:N ratio of the straw in the 6-turn treatment decreased from 57 to 16 by March 2 (after 3 turns), about 28 weeks after the windrows were formed (Table 1). There was no appreciable rainfall until late October, 10 weeks after the windrows were formed.

These results suggest that growers composting this type of straw can achieve nearly the maximum reduction in volume with as few as two turns. In conjunction with an appreciable amount of precipitation, growers interested in the most rapid reduction in volume should plan to turn compost windrows four or more times, timing the turns according to decreases in the temperature of the composting straw. In this study, the temperature of the straw increased rapidly after turning.

During composting, the internal temperature of the straw windrows increased; the higher temperatures indicated that moisture, oxygen and nutrient availability were favorable for thermophilic microorganism activity. A higher temperature during composting is desirable to kill weed seeds and pests that could contaminate subsequent crops. Viable crop seed is a concern to producers of certified seed. A temperature of 55–60°C lasting a few minutes to a few days is considered sufficient to kill most types of seeds and disease propagules (Biddlestone et al., 1987; Golueke, 1991). Sustained average temperatures of 50°C or more were attained in the straw windrows turned at least four times. The mean internal temperature over the 32 week monitoring period is shown for each turning rate (Fig. 2).

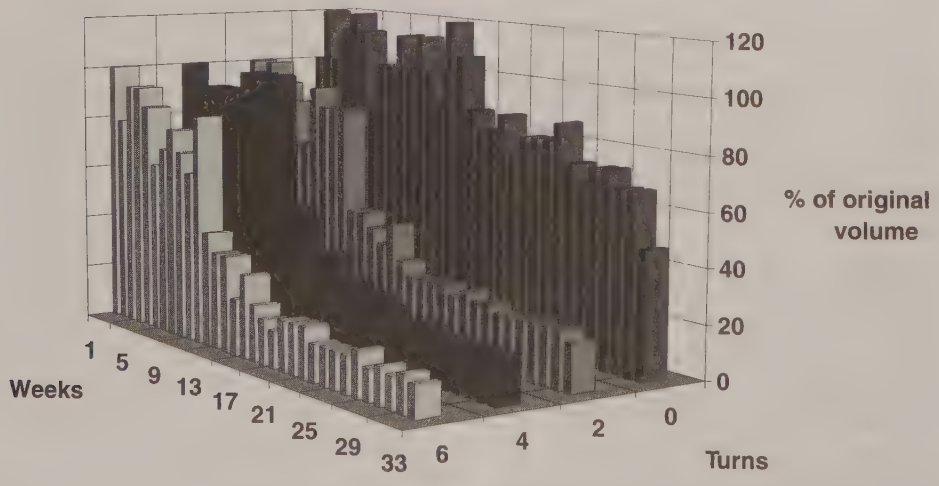

Figure 1. Percent of original volume remaining in straw windrows with zero to six turns.

Summary

The composting study showed that with natural rainfall, at least two turns were required to reduce the volume of straw by 80% or more in 20 to 24 weeks. Decomposition of straw residue with a high C:N ratio conflicts with established composting methods, where a C:N ratio less than 30 is thought to be required to compost grass straw. In this study, composting of grass straw residue was feasible without first having to lower the C:N ratio.

Composting is valuable both to dispose of straw and to recycle nutrients in the cropping system. Straw windrows in this study were reduced in volume by as much as 88% over 32 weeks, making composting an

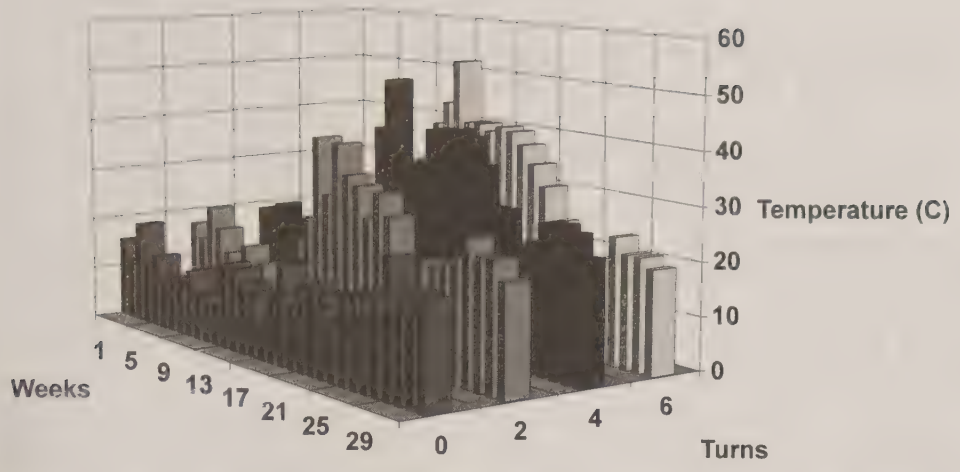

Figure 2. Mean internal temperature of straw windrow plots with zero to six turns through 32 weeks of monitoring.

attractive alternative to open field burning for disposing of straw. Additional studies are being conducted using a front-end loader to turn the compost in place instead of the commercial straddle-type turner. This may result in lower inputs and costs to the farmer.

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References

1. Biddlestone, A.J., K.R. Gray, and C.A. Day. 1987. Composting and straw decomposition. In C.F. Forster and D.A. Wase (eds). Environmental Biotechnology. John Wiley and Sons, New York, N.Y. pp. 135–175.
2. Bollen, G.J. 1985. The fate of plant pathogens during composting of crop residues. In J.K.R. Gasser (ed). Composting of Agricultural and Other Wastes. Elsevier Applied Science Publishers, London, England. pp. 282–290.
3. Bremner, J.M., and C.S. Mulvaney. 1982. Nitrogen—Total. In A.L. Page, R.H. Miller, and D.R. Keeney (eds). Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. 2nd ed. Amer. Soc. Agronomy, Madison, Wisconsin. pp. 595–624.
4. Churchill, D.B., D.M. Bilsland, and L.F. Elliott. 1995. Methods for composting grass seed straw residue. Applied Engineering in Agriculture 11:275–279.
5. Golueke, C.G. 1991. Principles of composting. In The Biocycle Guide to the Art and Science of Composting. The JG Press, Inc., Emmaus, Pennsylvania.
6. Hammouda, G.H.H., and W.A. Adams. 1987. The decomposition, humification and fate of nitrogen during composting of some plant residues. In M.D. Bertoldi, M.P. Ferranti, P. L'Hermite, and F. Zucconi (eds). Compost: Production, Quality and Use. Elsevier Applied Science, New York, N.Y. pp. 245–253.
7. Hoitink, H.A.J., Y. Inbar, and M.J. Boehm. 1991. Status of compost-amended potting mixes naturally suppressive to soilborne diseases of floricultural crops. Plant Disease 75:869–873.
8. Hornick, S.B., L.J. Sikora, S.B. Sterrett, J.J. Murray, P.D. Millner, W.D. Burge, D. Colacicco, J.F. Parr, R.L. Chaney, and G.B. Willson. 1984. Utilization of sewage sludge compost as a soil conditioner and fertilizer for plant growth. Agric. Information Bull. No. 464. U.S. Dept. of Agric., Washington, D.C.
9. Mackey, J.E. 1991. Opportunities in grass straw utilization. Prepared for the Oregon Economic Development Dept. and the Oregon Dept. of Agric. Prepared by CH2M-Hill in conjunction with Oregon State University, Corvallis.
10. Nelson, D.W., and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. In A.L. Page, R.H. Miller, and D.R. Keeney (eds). Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. 2nd ed. Amer. Soc. Agronomy, Madison, Wisconsin. pp. 539–579.
11. Rynk, R. 1992. On-farm composting handbook. NRAES-54. Northeast Regional Agricultural Engineering Service, Cornell University, Ithaca, New York.
12. Young, W.C. III, T.B. Silberstein, and D.O. Chilcote. 1993. Evaluation of equipment used by Willamette Valley grass seed growers as a substitute for open-field burning. Final report prepared for the Oregon Dept. of Agriculture's Alternatives to Open-field Burning Research Program, Corvallis, OR.

INSTITUTE NEWS
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Jason Halbert Is Wallace Institute's First Ward Sinclair Intern

Jason Halbert of West Chester, Pennsylvania, has been named the first recipient of the Wallace Institute's Ward Sinclair Memorial Internship. Beginning in July, Halbert will spend six months working at the Flickerville Mountain Farm and Ground Hog Ranch in Dott, Pennsylvania, the farm established and managed by the late Ward Sinclair and Cass Peterson, and he will be working with the Pennsylvania Association for Sustainable Agriculture. At PASA, he will investigate farmer/consumer demographics in Pennsylvania to determine the best potential producer-only markets in Pennsylvania, and he will travel throughout the state to encourage local markets. He worked at the Flickerville Mountain Farm last year, and he has also worked as a grassroots lobbyist and organizer for a forest protection organization.

The Internship is sponsored by the Wallace Institute to honor the late Ward Sinclair, an organic farmer, a writer, and a member of the Wallace Institute's Board of Directors.

Economic methods for comparing alternative crop production systems: A review of the literature

Wayne S. Roberts and Scott M. Swinton

Abstract. *New crop production technologies developed in response to growing concern over environmental contamination from agriculture may be neither more profitable nor higher yielding than the systems they replace, but they often reduce environmental contamination or improve soil and water quality. Systems designed with environmental objectives cannot be evaluated fairly just by productivity, which is what often is done in economic studies of alternative systems. We review 58 recent studies comparing alternative crop production systems to identify the key criteria for system comparisons, the system characteristics important in designing the analysis, and the methods most suited for comparing alternative systems.*

The four key criteria we looked for in system comparisons are expected profit, stability of profits, expected environmental impacts, and stability of environmental impacts. Most economic studies of crop production focus exclusively on profitability, and incorporate neither environmental criteria nor the dynamic characteristics inherent in alternative systems. We identify promising new approaches that take account of specific environmental characteristics and attempt to balance the objectives of profitability and environmental risk management. Balanced environmental-economic analysis is most likely to be achieved by integrating biophysical simulation models with economic optimization methods to model the trade-offs among profitability, environmental impact, and system stability (both financial and environmental).

Key words: alternative agriculture, analytical methods, crop systems, economic analysis, environmental management, profitability, risk, stability

Introduction

In response to growing concern over environmental contamination and consumer resistance to food perceived as tainted by pesticides, many farmers and researchers have begun developing alternative crop production systems. Typically, these systems are neither more profitable nor higher yielding than the systems they replace. However, they often result in less contamination of ground and surface waters, less pesticide residue on the marketed product, or better soil quality. Having been designed to attain these environmental objectives, these systems cannot be evaluated fairly on productivity criteria alone.

Until recently, productivity criteria were almost all that economists and agronomists considered in evaluating agricultural technology. Since World War II, most U.S. crop research has focused on reducing labor requirements and increasing yields per unit of land (Hayami and Ruttan, 1985). Economic evaluations of new crop technology have focused on profitability. Yield increases by themselves raise profits, so the only issue was whether the value of the yield increase justified the cost incurred to obtain it.

Three factors complicate comparisons between the new alternative cropping systems and "conventional" ones: expanded performance criteria, the diversity of the technologies, and production of multiple products. Comparisons are most complicated when more than one performance criterion is desired and different systems excel at different criteria. Different performance criteria may be transformed into a single index (for example, Higley and Wintersteen, 1992; Kovach et al., 1992; Teague et al., 1995a,b,c), or compared one-by-one using some dominance criterion (e.g., Bouzaher et al., 1992; Hoag and Hornsby, 1992). How closely the technologies are related determines whether a "nested" statistical evaluation can be conducted. That is, if one technology is inherently contained within another (such as a lower fertilizer rate within a higher rate), then comparisons are direct and simple. On the other hand, if two technologies are very different, the comparison may be much more complicated, such as annual application of inorganic N fertilizer compared with organic soil amendments that may take years to reach the desired equilibrium level of N mineralization. Most farms produce many products, yet standard economic comparisons treat individual outputs as if they were unrelated. A particular complication is how much weight to give to undesirable side effects of production (Beattie et al., 1974).

In this paper, we review recent literature comparing alternative and "conventional" cropping systems on the field and farm level. We do not address all sustainable

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agricultural and food systems issues, nor the socioeconomic ramifications of industrial versus traditional agriculture. Instead, we build on the previous literature review by Fox et al. (1991) by identifying important comparison criteria and developing a typology for economic analyses of North American cropping systems. We then evaluate the methods used to compare crop systems, with the goal of identifying those best suited for specific kinds of comparisons.

Criteria for Comparison

Profitability and environmental impact are the two performance criteria of greatest interest for contemporary comparisons, with profitability the main criterion in economic comparisons. Profit refers to the net financial return after the farm operator has paid all fixed and variable expenses. Many studies reviewed here used gross margin as a proxy for profit; gross margin is the return over specified variable costs.

However, average profitability is an inadequate criterion by itself, since it ignores risk. As Conway (1994) notes, a measure of profit stability is required as well. From an economic perspective, income stability is the interesting measure. It is inherently dynamic, since stability cannot be measured in a single period. The number of production periods sufficient for a reliable evaluation remains an empirical issue tied to the type of comparison.

Any crop production technology has environmental consequences, which may involve air, land, water, or the health and ecological status of living organisms. Here we focus on direct effects from using technology on the farm. The effects of greatest interest will vary with the technology, but important ones include energy use, soil erosion, and leaching and runoff of chemicals. As with profitability, it is not just the average environmental effect that matters, but also its stability.

Systems and Technology Types

The economic literature on cropping systems typically starts from a baseline called "conventional." To this are compared alternative systems that typically use less tillage, less mineral fertilizer, or less pesticide. The alternative systems may use lower amounts of existing technology, or they may introduce new technology. The latter category includes such practices as flex cropping and integrated pest management (IPM), which substitute information for physical inputs. Alternative crop nutrition techniques include rotations, cover crops, and manure applications as substitutes for mineral fertilizers.

Most alternative systems are designed primarily to reduce a specific environmental impact, especially soil erosion or contamination by fertilizers and pesticides, with reducing costs a secondary objective. More than one environmental criterion may be needed to compare systems, since alternative systems designed to meet one environmental objective, such as reduced soil erosion, may be inconsistent with a different one, such as reduced chemical leaching (Crowder et al., 1985; Painter et al., 1992; Foltz et al., 1993). Ironically, the most elusive system to characterize seems to be the "conventional" benchmark. Since conventional farming practices are always evolving, the benchmarks used should be typical of common practices for the time and location of the study.

System Characteristics Important to Designing the Analysis

The dynamic features of many alternative systems, such as rotations and biological pest control, imply that comparisons should allow sufficient time for the system to adjust to biological changes and for the operator to learn how to manage the new system (Lockeretz et al., 1978; Dabbert and Madden, 1986; Hanson et al., 1990). Resource degradation, such as soil erosion, occurs gradually, and remedial practices like conservation tillage and crop rotations take years to make a difference (Crowder et al., 1985; Helmers et al., 1986; Baffoe et al., 1987; Goldstein and Young, 1987; Sahs et al., 1988; Zentner et al., 1988; Lesoing and Francis, 1993).

A second important system characteristic is responsiveness to shocks from weather, product prices or input costs. Systems with lower investments in purchased inputs tend to be less susceptible financially to input price shocks. Some crop systems tend to yield more reliably in the face of unusual rainfall levels (Shearer et al., 1981; Sahs et al., 1988; Mends et al., 1989). Both economic and physical characteristics affect the income stability criterion, though separating cost, price, and yield effects is analytically important (Helmers et al., 1986).

This paper is focused on the farm level, but when many farms make a change at once, it can have additional effects on both profitability and environmental impacts for an individual farm. For example, widespread adoption of an alternative system can change the supply of a crop and thereby change its price (Olson et al., 1982; Langley et al., 1983; Knutson et al., 1990). The profitability of an alternative system, especially an organic system, may depend on premium prices; a significant increase in the supply over demand can substantially reduce the premiums received (Batte et al., 1993).

The environmental resource endowment is a third characteristic that should be explicitly incorporated into most comparisons. All else being equal, systems that reduce soil erosion will offer greater benefits on highly erodible soils or where surface water quality is highly valued (Faeth, 1993). Similarly, heavy soils with poor water infiltration are less likely to allow chemical leaching into groundwater than light, sandy soils (Cox and Easter, 1990). Systems are designed to meet environmental objectives for specific settings, so the setting is important in designing system comparisons (see McQueen et al., 1982; Schoney and Thorson, 1986).

Cropping systems are also characterized by different demands for labor, capital, and management skills. Alternative systems may call for more knowledge and labor from the farm manager, but less equipment and chemical inputs. These differences need to be accounted for in the analysis.

Finally, some cropping systems may have environmental side-effects that diminish their appeal. An example is an organic or low-chemical system that relies on increased tillage, with a corresponding increase in soil erosion; conversely, a conservation tillage system may rely on increased herbicide use for weed control (Crowder et al., 1985; Zentner et al., 1988; Dobbs, 1994). Important side-effects should be incorporated explicitly into system comparisons.

Methods for Comparing Systems

The choice of analytical method largely depends on the performance criteria of

interest. Table 1 matches analytical methods to performance criteria for most of the 58 U.S. and Canadian studies reviewed here. The performance criteria are divided into average profitability, average environmental impact, and stability of profits and of environmental impact. However, environmental stability was analyzed only by Teague et al. (1995a) and Carriker (1995).

Enterprise budgets are the predominant method for comparing profitability, providing a focus for evaluating the costs and returns of alternative systems. (See Table 1 for a list of studies using them for this purpose.)

Uncertainty about prices and yields in enterprise budgets can be accommodated partially using sensitivity or break-even analysis. Sensitivity analysis brackets a baseline enterprise budget with more favorable and more unfavorable scenarios (e.g., Helmers et al., 1986; Dobbs et al., 1988; Sahs et al., 1988; Westra and Boyle, 1992; Diebel et al., in press). It shows the stability of an outcome under a range of plausible assumptions about risky, uncontrollable factors such as prices and yields. Break-even analysis identifies the yield, price, or cost threshold at which enterprise revenues would just equal costs (including opportunity costs) (Schoney and Thorson, 1986; Hilker et al., 1987; Mends et al., 1989; Painter et al., 1992). If the probability distribution of the random variable is known, both kinds of analysis provide rough confidence levels for profitability.

"Green" budgeting is a new approach that includes explicit environmental costs and benefits in an enterprise budget. Faeth (1993) used off-site social costs of $0.66 to $8.16 per ton of eroded soil, based on regional estimates from a comprehensive national study by Ribaudo (1986). Higley and Wintersteen (1992) estimated environmental costs of pesticides from a questionnaire survey to calculate IPM "environmental thresholds" for pest control. Although green budgeting can be applied to many environmental and health attributes, the potential subjectivity of the value placed on environmental quality has limited its use.

Enterprise budgets are the building blocks for whole farm analysis. Seven studies extended their enterprise budgets to a whole farm analysis (Klepper et al., 1977; Dobbs et al., 1988; Mends et al., 1989; Hanson et al., 1990; Batte et al., 1993; Irwin-Hewitt and Lohr, 1993; Diebel et al., in press).

Table 1. Classification of literature by performance criterion and analytical method.

	Performance Criterion		
Analytical method	**Profitability**	**Stability (finan./envir.)**	**Environmental Impact**
Enterprise budgets	Berardi		
	Chase & Duffy		
	Diebel & Williams		
	Dobbs (93,94)		
	Dobbs et al.	Dobbs et al.	
	Faeth	Faeth	
	Goldstein & Young		
	Hanson et al.		
	Helmers et al.	Helmers et al.	
	Ikerd et al.		Ikerd et al.
	Lazarus et al.		
	Legg et al.		
	Lockeretz et al. (78,81)		
	Mends et al.		
	Moffitt et al.	Moffitt et al.	
	Painter et al.		
	Sahs et al.	Sahs et al.	
	Shearer et al.		
	Smolik et al.	Smolik et al.	Smolik et al.
	Westra & Boyle	Westra & Boyle	
	Young & Painter		
	Zentner et al.		
Break-even analysis	Diebel et al.		Diebel et al.
	Mends et al.		
	Painter et al.		
	Schoney & Thorson		
Whole farm analysis (not LP)	Diebel et al.		
	Dobbs et al.		
	Hanson et al.	Hanson et al.	
	Ikerd		Ikerd
	Irwin-Hewitt & Lohr		Irwin-Hewitt & Lohr
	Klepper et al.		
	Mends et al.		
Linear programming (LP)	Baffoe et al.		Baffoe et al.
	Crowder et al.		Crowder et al.
	Dabbert & Madden		
	Domanico et al.		Domanico et al.
	Faeth		Faeth
	Foltz et al.		
	Johnson et al.		
	Langley et al.	Langley et al.	
	Lazarus et al.		
	Lazarus & White		
	McQueen et al.		McQueen et al.
	Olson et al.	Olson et al.	
	Swinton & Clark		Swinton & Clark
	Taylor et al.		
	Teague et al. (95a,b)	Teague et al. (95a,b)	
	Xu et al.		

Table 1. Classification of literature by performance criterion and analytical method (*continued*).

Analytical method	Performance Criterion: Profitability	Stability (finan./envir.)	Environmental Impact
Dynamic programming	Bole & Freeze Johnson et al. Schoney & Thorson Van Kooten et al. Young & Van Kooten		Van Kooten et al.
Biophysical simulation		Bole & Freeze Teague et al. (95a,b)	Crowder et al. Foltz et al. Johnson et al. Taylor et al. Teague et al. (95a,b) Teague et al. (95c) Xu et al.
Dominance	Bouzaher et al. Carriker Hoag & Hornsby Xu et al.	Carriker	Bouzaher et al. Carriker Hoag & Hornsby Xu et al.
Index of environmental impact	Teague et al. (95a,b) Teague et al. (95c)	Teague et al. (95a,b)	Higley & Wintersteen Kovach et al. Teague et al. (95c)

A useful tool for whole farm analysis is the PLANETOR computer-based decision support system (Ikerd, 1991). PLANETOR evaluates how alternative technologies and strategies affect average profitability and the environment. The new version links site-specific farm data with the Nitrogen Leaching and Economic Analysis Package, the Revised Universal Soil Loss Equation, and other simulation models and databases to predict environmental and human health risks from erosion, leaching, runoff, and pesticide toxicity (Center for Farm Financial Management, 1995). These numerical estimates supplement the "high-medium-low" ratings in the 1991 version. PLANETOR also projects financial outcomes and the balance between farm resource use and availability. The model can be used to evaluate crop systems for both profitability and environmental risks.

Linear programming (LP) is a mathematical technique for optimizing an objective within a set of constraints. In farm management analyses, LP is most commonly used to maximize farm profit with a fixed supply of land, labor, and equipment. It also can be used to measure how environmental standards or alternative crop systems are likely to affect profit (Table 1). Multi-period LP is used when time is a key factor, such as in studying how a crop rotation affects soil erosion (Baffoe et al., 1987), or the transition to organic farming (Dabbert and Madden, 1986). Another use of LP is in interregional analysis, such as to evaluate the impact of nationwide adoption of organic practices (e.g., Olson et al., 1982; Langley et al., 1983). Although there are well-established LP models for managing financial risk, a promising new extension of this approach shows how to maximize net financial returns while keeping environmental risk below a critical level (e.g., Teague et al., 1995a,b).

Dynamic programming (DP) also is used for profitability comparisons. DP is a mathematical tool for solving multi-stage decision problems, such as whether to crop a field or put it into summer fallow (Bole and Freeze, 1986; Young and van Kooten, 1989). Non-optimizing dynamic simulation was used in another study to determine the long-term effects of extending crop rotations (Schoney and Thorson, 1986).

Although DP is used primarily to analyze profitability, the data required for a DP model often come from biophysical simulation models of processes such as crop growth or the fate of chemicals in the environment (Crowder et al., 1985; Foltz et al., 1993). It is increasingly common to link biophysical process models with economic models (Antle and Capalbo, 1993). Plant simulation models can be used to compare the stability of different systems by predicting crop yields for different input levels or weather (Bole and Freeze, 1986; Johnson et al., 1991; Taylor et al., 1992). However, biophysical simulation requires substantial input data, such as daily temperature, precipitation and radiation, and careful empirical validation of the results. Even when these models are validated in the area for which they were designed, they may perform poorly elsewhere. However, when properly validated, biophysical simulation models offer a rapid, low cost way to conduct controlled experiments by computer. Their results can show both the crop performance and the environmental side effects of alternative cropping systems.

Comparing Multiple Criteria

A major challenge is to measure the many possible environmental impacts of a new cropping system. Two approaches have been taken in the studies reviewed: indexing and dominance analysis. Indexing creates a weighted index that integrates all the criteria that a decisionmaker cares about. Ikerd (1991) and the Center for Farm Financial Management (1995) took this path in designing PLANETOR, which allows financial outcomes to be compared with three classes of environmental risks. The "environmental impact quotient" of Kovach et al. (1992) is an index of pesticide impacts. Teague et al. (1995b,c) developed two indexes to incorporate the effects of environmental risk on farmers' decisionmaking. One index measures the level of environmental risk from pesticides, the other measures risk from nitrates. Higley and Wintersteen (1992) followed an index-like approach to construct a measure of "environmental costs" of pesticides. To the market price of pesticides and the cost of application, they added farmers'

willingness to pay for reduction of environmental risks as expressed in a mail survey.

Although indexing is attractive because it combines many complex factors into a single measure, it is open to criticism because of subjectivity in assigning relative weights to the components of the index. Teague et al. (1995c) addressed this criticism by developing three alternative indexes of environmental risk that incorporate different environmental effects of pesticide use. One index considers only chemical characteristics, and is similar to the "environmental impact quotient" of Kovach et al. (1992); the other two incorporate estimates of expected annual chemical runoff and percolation. They found that despite differences in how the indexes were constructed, rankings of crop production alternatives under the different indexes were strongly and positively correlated. This suggests they all might lead to similar environmental policies, although with differing economic consequences.

Whereas an index combines different criteria into one number, dominance analysis uses the individual numbers associated with each criterion. For two desired criteria, i.e., farm profit and soil quality (Van Kooten et al., 1990), dominance analysis identifies practices that increase one without decreasing the other. This results in a trade-off frontier showing the most profitable cropping practice available at each level of expected soil quality. In this example, higher short-term profits might require cropping practices that would decrease soil quality because of erosion. Therefore, the choice of "best" practice is left to the decisionmaker's personal preferences.

Dominance analyses have proliferated recently. Hoag and Hornsby (1992) used it to construct cost-environmental hazard frontiers that identify the trade-off between financial cost and environmental hazard for herbicides in southeastern soybeans. Bouzaher et al. (1992) used a similar approach to highlight trade-offs between the probability of crop loss and the cost of weed control under various herbicide bans. Swinton and Clark (1994) examined the trade-off between leachable nitrate and farm gross margin, while Xu et al. (1995) extended this approach to include soil erosion and leachable nitrate. Carriker (1995) used a related method called "stochastic dominance with respect to a function" to examine trade-offs between profitability and both income and nitrate loading risk for different corn fertilization strategies. Ess et al. (1994) used energy use and net return dominance to compare corn silage production methods for alternative nitrogen sources. A treatment was considered superior if it was lower in energy input per unit of crop output while its net revenue was not statistically different from the baseline treatments.

Effectiveness of Various Methods

The main objective of studies comparing alternative crop production systems typically is to assess the impact of a new technology or a new or proposed policy, or else to provide decision support for farm managers. The study objective and the importance attached to nonfinancial criteria are central to choosing the best analysis method.

Most budgeting methods fail to evaluate environmental criteria. Two limited exceptions are green budgeting (Faeth, 1993) and break-even budgeting based on meeting an environmental target. For environmental impact analysis, budgets have been supplemented by nonmonetary accounting for an environmental criterion such as soil loss (see Ikerd et al., 1993). However, unless supplemented by dominance analysis, financial budgeting provides no clear guidance for ranking different systems. Budgeting methods also miss whole-farm constraints, such as workable field time, which may not be limiting at the individual enterprise level.

At the other extreme, biophysical simulation models portray environmental processes in detail but offer no economic basis for evaluating crop systems. Getting a balanced evaluation requires compromising on the level of detail on both the financial and environmental sides. The variety of important environmental criteria forces analysts to focus on key ones, which may cause them to miss interrelationships, or else to build indexes from multiple criteria.

Few studies have captured dynamic effects, yet these are central to the definition of sustainable systems. Dabbert and Madden (1986) made an effort with multi-period LP, but their study was based on limited biological data. Dynamic programming studies have modeled changing environmental conditions, but except Van Kooten et al. (1990), those reviewed did not include any index that translates environmental quality into monetary terms. All the rest are driven by "value functions" defined strictly in financial terms, with environmental quality outside the optimization criterion.

Teague et al. (1995a) offer a promising approach to balancing profitability and environmental risk management. Their farm-level risk programming model evaluates changes in cropping patterns and farm incomes associated with reducing environmental risk from nitrates in groundwater. They use an LP method called Target MOTAD (Tauer, 1983), which was designed to maximize net returns while insuring a minimum probability that returns remain above a target level. Instead of an income target, Teague et al. (1995a) set a threshold for maximum nitrate contamination of groundwater. Instead of a minimum probability of meeting the income target, they substituted a minimum acceptable probability of complying with the threshold. By changing the nitrate thresholds and compliance levels, they captured the trade-off between expected income and the environmental risk from nitrate loadings, as simulated by the Erosion Productivity Impact Calculator model with the pesticide subroutines from the Groundwater Loading Effects of Agricultural Management Systems model.

A balanced economic and environmental analysis of alternative systems typically would follow either of two approaches. One is to place a monetary value on environmental impacts (Higley and Wintersteen, 1992; Faeth, 1993) and include them into a monetary objective function to be maximized. The other is to treat environmental impacts as parameters in an optimization model (Crowder et al., 1985; Johnson et al., 1991; Swinton and Clark, 1994; Teague et al., 1995a,b; Xu et al., 1995), or to build efficiency frontiers, as in dominance analysis (Van Kooten et al., 1990; Bouzaher et al., 1992; Hoag and Hornsby, 1992; Carriker, 1995).

To execute either approach effectively requires a minimum amount of data for joint microeconomic and environmental analysis of alternative crop systems. First, levels of resource use and financial costs are needed, including complete data on all aspects that differ between systems. Second, yields of marketable products should be monitored, including performance, as they evolve over time under different natural

conditions. Third, the analysis should include complete data on the environmental parameters that vary significantly across systems, such as nitrate leaching, soil erosion, or applications of synthetic chemicals.

Putting a monetary value on environmental quality also requires assigning a value to reductions in environmental risks. Although attractive in theory, the high cost and potential subjectivity of this approach are why it has seldom been applied in analyzing alternative crop systems. Consequently, the most promising current analytical techniques link biophysical simulation models to an economic optimization model. These will only be as good as the data from which they are constructed, and they must be validated within the study area.

Conclusions

Efforts to evaluate both the economic and environmental attributes of alternative cropping systems are still immature. The particularity of environmental issues defies prescriptions for a generalized approach, but system stability and evolution are two areas that deserve more careful study. This is true for all three main uses of these economic analyses: technology evaluation, policy analysis, and decision-support systems. When care is taken to assure data quality, existing economic optimization methods linked to biophysical simulation models have a demonstrated potential for evaluating the trade-offs among expected profitability, environmental impacts, and both financial and environmental stability.

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References

1. Antle, J.M., and S.M. Capalbo. 1993. Integrating economics and physical models for analyzing environmental effects of agricultural policy on nonpoint-source pollution. In C.S. Russell and J.F. Shogren (eds). Theory, Modeling and Experience in the Management of Nonpoint-Source Pollution. Kluwer, Boston, Massachusetts. pp. 155–178.
2. Baffoe, J.K., D.P. Stonehouse, and B.D. Kay. 1987. Methodology for farm-level economic analysis of soil erosion effects under alternative crop rotational systems. Canadian J. Agric. Economics 35:55–74.
3. Batte, M.T., D.L. Forster, and F.J. Hitzhusen. 1993. Organic agriculture in Ohio: An economic perspective. J. Production Agric. 6:536–542.
4. Beattie, B., S. Thompson, and M. Boehlje. 1974. Product complementarity in production: The by-product case. Southern J. Agric. Economics 6:161–165.
5. Berardi, G.M. 1978. Organic and conventional wheat production: Examination of energy and economics. Agroecosystems 4:367–376.
6. Bole, J.B., and B.S. Freeze. 1986. Modeling the economic returns from fixed and soil moisture-based flexible rotations. Canadian Farm Economics 20:15–20.
7. Bouzaher, A., D. Archer, R. Cabe, A. Carriquiry, and J. Shogren. 1992. Effects of environmental policy on trade-offs in agri-chemical management. J. Environmental Management 36:69–80.
8. Carriker, G.L. 1995. Factor input demand subject to economic and environmental risk: Nitrogen fertilizer in Kansas dryland corn production. Review Agric. Economics 17:77–89.
9. Center for Farm Financial Management. 1995. PLANETOR User's Manual. Version 2.0. Dept. of Agric. and Applied Economics, Univ. of Minnesota, St. Paul.
10. Chase, C., and M. Duffy. 1991. An economic comparison of conventional and reduced-chemical farming systems in Iowa. Amer. J. Alternative Agric. 6:168–173.
11. Conway, G.R. 1994. Sustainability in agricultural development: Trade-offs between productivity, stability, and equitability. J. Farming Systems Research-Extension 4(2):1–14.
12. Cox, C.A., and K.W. Easter. 1990. A regional ban of alachlor and atrazine in southeastern Minnesota: The economic and environmental impacts. Staff Paper P90–58. Dept. of Agric. and Applied Economics, Univ. of Minnesota, St. Paul.
13. Crowder, B.M., H.B. Pionke, D. J. Epp, and C.E. Young. 1985. Using CREAMS and economic modeling to evaluate conservation practices: An application. J. Environmental Quality 14:428–434.
14. Dabbert, S., and P. Madden. 1986. The transition to organic agriculture: A multi-year simulation model of a Pennsylvania farm. Amer. J. Alternative Agric. 1:99–107.
15. Diebel, P.L., and J.R. Williams. 1993. An economic analysis of the Integrated Farm Management Program Option for corn and wheat rotations. Review of Agric. Economics 15:417–429.
16. Diebel, P.L., J.R. Williams, and R.V. Llewelyn. (in press). An economic analysis of conventional and alternative cropping systems for a representative northeast Kansas farm. Review of Agric. Economics.
17. Dobbs, T.L. 1993. Implications of sustainable farming systems in the northern Great Plains for farm profitability and size. Staff Paper 93-5. Economics Dept., South Dakota State Univ., Brookings.
18. Dobbs, T.L. 1994. Organic, conventional, and reduced till farming systems: Profitability in the northern Great Plains. Choices 9(2nd Quarter):31–32.
19. Dobbs, T.L., M.G. Leddy, and J.D. Smolik. 1988. Factors influencing the economic potential for alternative farming systems: Case analysis in South Dakota. Amer. J. Alternative Agric. 3:26–34.
20. Domanico, J.L., P. Madden, and E.J. Partenheimer. 1986. Income effects of limiting soil erosion under organic, conventional, and no-till systems in eastern Pennsylvania. Amer. J. Alternative Agric. 1:75–82.
21. Ess, D.R., D.H. Vaughan, J.M. Luna, and P.G. Sullivan. 1994. Energy and economic savings from the use of legume cover crops in Virginia corn production. Amer. J. Alternative Agric. 9:178–185.
22. Faeth, P. 1993. Evaluating agricultural policy and the sustainability of production systems: An economic framework. J. Soil and Water Conservation 48:94–99.
23. Foltz, J.C., J.G. Lee, and M.A. Martin. 1993. Farm-level economic and environmental impacts of eastern corn belt cropping systems. J. Production Agric. 6:290–296.
24. Fox, G., A. Weersink, G. Sarwar, S. Duff, and B. Deen. 1991. Comparative economics of alternative agricultural production systems: A review. Northeastern J. Agric. and Resource Economics 20:124–142.
25. Goldstein, W.A., and D.L. Young. 1987. An agronomic and economic comparison of a conventional and a low-input cropping system in the Palouse. Amer. J. Alternative Agric. 2:51–56.
26. Hanson, J.C., D.M. Johnson, S.E. Peters, and R.R. Janke. 1990. The profitability of sustainable agriculture on a representative grain farm in the mid-Atlantic

region, 1981–89. Northeast J. Agric. and Resource Economics 19:90–98.
27. Hayami, Y., and V.W. Ruttan. 1985. Agricultural Development: An International Perspective. 2nd ed. Johns Hopkins Univ. Press., Baltimore, Maryland.
28. Helmers, G.A., M.R. Langemeier, and J. Atwood. 1986. An economic analysis of alternative cropping systems for east-central Nebraska. Amer. J. Alternative Agric. 1:153–158.
29. Higley, L.G., and W.K. Wintersteen. 1992. A novel approach to environmental risk assessment of pesticides as a basis for incorporating environmental costs into economic injury level. Amer. Entomologist 38:34–39.
30. Hilker, J.H., J.R. Black, and O.B. Hesterman. 1987. Break-even analysis for comparing alternative crops. Extension Bull. E-2021. MSU Extension, Michigan State Univ., East Lansing.
31. Hoag, D., and A. Hornsby. 1992. Coupling groundwater contamination with economic returns when applying farm pesticides. J. Environmental Quality 21:579–586.
32. Ikerd, J.E. 1991. A decision support system for sustainable farming. Northeastern J. Agric. and Resource Economics 20:109–113.
33. Ikerd, J., S. Monson, and D. Van Dyne. 1993. Alternative farming systems for U.S. agriculture: New estimates of profit and environmental effects. Choices 8(3rd Quarter):37–38.
34. Irwin-Hewitt, T., and L. Lohr. 1993. Economic and environmental impacts of alternative cropping sequences in Michigan. Agricultural resources: Inputs situation and outlook. AR-29. Economic Research Service, U.S. Dept. of Agric., Washington, D.C. pp. 40–43.
35. Johnson, S.L., R.M. Adams, and G.M. Perry. 1991. The on-farm costs of reducing groundwater pollution. Amer. J. Agric. Economics 73:1063–1073.
36. Klepper, R., W. Lockeretz, B. Commoner, M. Gertler, S. Fast, D. O'Leary, and R. Blobaum. 1977. Economic performance and energy intensiveness on organic and conventional farms in the corn belt: A preliminary comparison. Amer. J. Agric. Economics 59:1–12.
37. Knutson, R.D., C.R. Taylor, J.B. Penson, and E.G. Smith. 1990. Economic impacts of reduced chemical use. Knutson and Associates, College Station, Texas.
38. Kovach, J., C. Petzoldt, J. Degni, and J. Tette. 1992. A method to measure the environmental impact of pesticides. New York Food and Life Sciences Bull. 139. New York State Agric. Exp. Sta., Geneva.
39. Langley, J.A., E.O. Heady, and K.D. Olson. 1983. The macro implications of a complete transformation of U.S. agricultural production to organic farming practices. Agric., Ecosystems and Environment 10:323–333.
40. Lazarus, S.S., and G.B. White. 1984. Economic impact of introducing rotations on Long Island potato farms. Northeastern J. Agric. and Resource Economics 13:221–228.
41. Lazarus, W.F., L.D. Hoffman, and E.J. Partenheimer. 1979. Evaluation of selected cropping systems on Pennsylvania dairy farms. J. Northeastern Agric. Economics Council 8:43–59.
42. Legg, T.D., J.J. Fletcher, and K.W. Easter. 1989. Nitrogen budgets and economic efficiency: A case study of southeastern Minnesota. J. Production Agric. 2:110–116.
43. Lesoing, G., and C. Francis. 1993. Rotation/manure effects on crop yields and soil characteristics at ARDC. Crop Production News 13.
44. Lockeretz, W., G. Shearer, R. Klepper, and S. Sweeney. 1978. Field crop production on organic farms in the Midwest. J. Soil and Water Conservation 33:130–134.
45. Lockeretz, W., G. Shearer, and D.H. Kohl. 1981. Organic farming in the corn belt. Science 211:540–547.
46. McQueen, A.D., R.N. Shulstad, and C.T. Osborn. 1982. Controlling agricultural soil loss in Arkansas' north Lake Chicot watershed: A cost analysis. J. Soil and Water Conservation 37:182–185.
47. Mends, C., T.L. Dobbs, and J.D. Smolik. 1989. Economic results of alternative farming systems trials at South Dakota State University's research station, 1985–1989. Research Rep. 89–3. Economics Dept., South Dakota State Univ., Brookings.
48. Moffitt, L.J., T.M. Burrows, J.L. Burrows, J.L. Baritelle, and V. Sevacherian. 1984. Risk evaluation of early termination for pest control in cotton. Western J. Agric. Economics 9:145–151.
49. Olson, K.D., J. Langley, and E.O. Heady. 1982. Widespread adoption of organic farming practices: Estimated impacts on U.S. agriculture. J. Soil and Water Conservation 37:41–45.
50. Painter, K., D. Granatstein, and B. Miller. 1992. 1992 alternative crop rotation enterprise budgets, eastern Whitman county, Washington. Farm Business Management Report EB1725. Cooperative Extension, Washington State Univ., Pullman.
51. Ribaudo, M.O. 1986. Regional estimates of off-site damages from soil erosion. In Thomas E. Waddell (ed). The Off-site Costs of Soil Erosion. Conservation Foundation, Washington, D.C. pp. 29–48.
52. Sahs, W.W., G.A. Helmers, and M.R. Langemeier. 1988. Comparative profitability of organic and conventional production systems in east-central Nebraska. In Global Perspectives on Agroecology and Sustainable Agriculture Systems. Proc. Sixth Int. Scientific Conf. of the International Federation of Organic Agric. Movements. Agroecology Program, Univ. of California, Santa Cruz.
53. Schoney, R.A., and T. Thorson. 1986. The economic impact of extended crop rotations on Saskatchewan grain farms. Canadian Farm Economics 20:21–26.
54. Shearer, G., D.H. Kohl, D. Wanner, G. Kuepper, S. Sweeney, and W. Lockeretz. 1981. Crop production costs and returns on Midwestern organic farms: 1977 and 1978. Amer. J. Agric. Economics 63:264–269.
55. Smolik, J.D., T.L. Dobbs, and D.H. Rickerl. 1995. The relative sustainability of alternative, conventional, and reduced-till farming systems. Amer. J. Alternative Agric. 10:25–35.
56. Swinton, S.M., and D.S. Clark. 1994. Farm-level evaluation of alternative policy approaches to reduce nitrate leaching from Midwest agriculture. Agric. and Resource Economics Review 23:66–74.
57. Tauer, L.W. 1983. Target MOTAD. Amer. J. Agric. Economics 65:606–610.
58. Taylor, M.L., R.M. Adams, and S.F. Miller. 1992. Farm-level response to agricultural effluent control strategies: The case of the Willamette Valley. J. Agric. and Resource Economics 17:173–185.
59. Teague, M.L., D.J. Bernardo, and H.P. Mapp. 1995a. Farm-level economic analysis incorporating stochastic environmental risk assessment. Amer. J. Agric. Economics. 77:8–19.
60. Teague, M.L., D.J. Bernardo, and H.P. Mapp. 1995b. Meeting environmental goals efficiently on a farm-level basis. Review of Agric. Economics 17:37–50.
61. Teague, M.L., H.P. Mapp, and D.J. Bernardo. 1995c. Risk indices for economic and water quality tradeoffs: An application to Great Plains agriculture. J. Production Agric. 8:405–415.

62. Van Kooten, G.C., W.P. Weisensel, and D. Chinthammit. 1990. Valuing trade-offs between net returns and stewardship practices: The case of soil conservation in Saskatchewan. Amer. J. Agric. Economics 72:104–113.
63. Westra, J.V., and K.J. Boyle. 1992. An economic analysis of crops grown in rotation with potatoes in Aroostook county, Maine. Maine Agric. Exp. Sta. Bull. 834. Dept. of Agric. and Resource Economics, Univ. of Maine, Orono.
64. Xu, F., T. Prato, and J.C. Ma. 1995. A farm-level case study of sustainable agricultural production. J. Soil and Water Conservation 50:39–44.
65. Young, D.L., and K.M. Painter. 1990. Farm program impacts on incentives for green manure rotations. Amer. J. Alternative Agric. 5:99–105.
66. Young, L., and G.C. van Kooten. 1989. Economics of flexible spring cropping in a summer fallow region. J. Production Agric. 2:173–178.
67. Zentner, R.P., C.W. Lindwall, and J.M. Carefoot. 1988. Economics of rotations and tillage systems for winter wheat production in southern Alberta. Canadian Farm Economics 22:3–14.

RESOURCES

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Organic farmers and conventional distribution systems: The recent expansion of the organic food market in Denmark

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Abstract. *In 1993, a breakthrough occurred for sales of organic food products in conventional supermarkets in Denmark. Since then, sales have increased markedly and consumers now have a choice between organic and conventional food products in nearly all supermarkets. This success owes much to the intense efforts of three main groups since the mid-1980s. First, organic farmers have increased production and successfully managed economic and organizational problems. Second, the Danish State has supported sales of organic products and farmers' conversion to organic farming by supporting marketing and product innovation and by organizing producers. Third, the largest Danish supermarket chain has contributed by its steady demand for organic products since 1981. Today, all major supermarkets in Denmark are supplied by conventional distributors that handle the products of small organic producer organizations. For nearly two years the system has kept up the positive effects of a market expansion process that was initiated by a major advertising campaign and a modest drop in consumer prices.*

Key words: organic agriculture, supermarkets, marketing cooperatives, conversion programs, sustainable agriculture

The Recent Change in the Danish Food Market

Danish agriculture is strongly oriented toward exports, exporting more than two-thirds of its production. This international success often is attributed to farmers' high level of formal education, a well-functioning advisory system run by the farmers' unions, and food processing industries dominated by large agricultural cooperatives. Danish farmers are homogeneous in size of holdings and types of production, and Danish food companies can deliver homogenous products at high prices to demanding international buyers. Furthermore, Danish agriculture is among the most industrialized in the European Union.

Against this background, it is hardly surprising that there is no long tradition for organic or other types of alternative agriculture in Denmark. Until about 1970, only a few farmers had converted to organic or biodynamic practices. Conversion intensified in the 1970s, and by 1980 the number of organic farms had reached about 150, with a total area of 2,000 ha. In 1987, an act was passed giving limited support to farmers converting to organic agriculture. Since then, the number of organic farms increased to 677 in 1994, with a total area of 21,145 ha (Plantedirektoratet, 1995).

Although only 0.8% of Danish farmland has been converted, organic foods have gained attention far out of proportion to their 3 to 4% share of the domestic market. (This figure reflects the fact that a large portion of conventional production is exported, and that some organic products are imported.) The attention being given to organic foods by all parts of the market is both reflected in and caused by the fact that the total domestic volume of fresh organic products doubled between August 1993 and June 1994 as the result of a major advertising campaign and a small drop in consumer price premiums to about 30% (Michelsen, 1994). The process is still going on, with the volume of organic products doubling from the first quarter of 1994 to the same period in 1995 (Torben Laursen, Assistant Director of FDB [the largest supermarket chain and the main distributor of organic food in Denmark], personal communication, May 1995). A further consequence has been a 60% increase in the number of organic farms in 1995 (Økologisk Jordbrug, May 1995).

The recent growth of the Danish market is remarkable, since in 1992 Danish organic farmers faced a stagnant market and drops in producer price premiums from levels that typically ranged from 30% to 150%, sometimes even higher. Despite fluctuations in sales and producer prices, the present positive market situation seems likely to endure, because it has taken place within conventional distribution systems that have been the target of many marketing efforts since 1987.

This development was not triggered by consumer demand for organic products. Rather, it was the farmers who decided to initiate production. They gained economic and regulatory support from the agricultural

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authorities and from conventional manufacturers and retailers. Against this background, distribution and marketing efforts were done by trial-and-error for several years. The main obstacle to development was the fundamental distribution problem stemming from small-scale organic production scattered throughout the country. In contrast, the Danish food market is highly centralized, dominated by a few supermarket chains supplied by a few agricultural cooperatives consisting mostly of conventional farmers.

The purpose of this article is to describe how the fundamental distribution problems were solved in a way that allowed organic products to penetrate the conventional food distribution system in Denmark. Such an analysis is of interest to other countries besides Denmark (Hecq and Vaessen, 1994; Lampkin and Padel, 1994). The argument starts with farmers' production, then moves to support from public and market organizations, and finally to consumer demand.

Danish Organic Farmers

Distributing Danish organic products through conventional channels has been very difficult because organic farms are few, small, and scattered throughout the country. Furthermore, organic farms rarely specialize, and their product mix differs from that of conventional farming. One major difference is that pigs, a very important export product in Danish agriculture, are nearly absent from Danish organic farming. On the other hand, 84% of all organic holdings have livestock, far more than in Danish agriculture as a whole. However, the fraction of organic holdings that have milk cows (24%) is similar to the figure for Danish agriculture as a whole (Plantedirektoratet, 1992; 1993). The number of organic milk producers is growing, an important reason that in recent years the shares of larger holdings (50 ha and more) have become comparable in organic and conventional agriculture.

Another problem in distributing organic products through conventional distribution systems is the difference in attitudes between organic and conventional farmers. Attitudes are important because the major food distributors in Denmark are dominated by conventional farmers, who often strongly oppose organic farmers' criticisms of conventional farming.

The general difference in attitudes is seen in the scale of attitudes towards agriculture ranging from conventional to alternative introduced by Beus and Dunlap (1991; 1993). The scale was adapted for Danish farmers by Bager and Søgaard (1994), who found organic farmers positioned at the alternative end of the scale. The difference in attitudes is further seen in the fact that organic farmers' second most important motivation for conversion was criticism of the development of conventional agriculture (Table 1). The most important motivation was concern for the environment, mentioned by two-thirds of all organic farmers; in contrast, only 3% of a representative sample of Danish farmers mentioned environmental stress as one of the three most important problems for Danish agriculture in 1993 (Bager and Søgaard, 1994, p. 36). At the lower end, only 10% of the organic farmers mentioned better economic prospects, which is generally assumed to be the dominant production motive among Danish farmers.

Danish organic holdings thus differ substantially from conventional ones, and organic farmers differ from conventional ones in their general attitudes towards agriculture and the environment and the reduced importance they give to economic considerations. Such differences at the outset seem to make it impossible to get organic and conventional farmers to cooperate in distributing products or in any other ways. However, some cooperation has developed. On the organizational level, the associations for organic farming cooperate closely with conventional farmers' unions on issues such as the extension service. In fact, the advisory system for organic farmers is run by the conventional farmers' unions.

Cooperation goes further, since many organic farmers also are members of conventional farmers' organizations. According to Jensen's survey (1992), 66% of all organic farmers belonged to a traditional farmers' union. At the same time, 70% of the organic farmers belonged to an organic organization, and 50% were members of both. Because certification is left to a public agency, organic farmers need not belong to an organic agriculture organization, and 13% of them were not members of either an organic or a conventional organization.

The partial cooperation between organic and conventional farmers' unions has been accompanied by hesitant rapprochements between organic farmers and conventional food distribution firms. Until the late 1980s, ordinary food firms generally refused to market organic products. Therefore, organic farmers had to develop their own marketing channels by selling directly to consumers, to local or specialized outlets, or to small private wholesaling or manufacturing firms specializing in organic products (as opposed to cooperatives dominated by conventional farmers). When organic production expanded in the late 1980s, these marketing channels were inadequate to take care of all products. The organic farmers eventually formed marketing organizations that cautiously began to look for partners among conventional firms. Some partners were found, but the partnership has not been easy.

In 1991, when Jensen (1992) did his survey, the marketing problems had become obvious. The organic farmers' attitudes towards marketing problems are shown in Table 2. Organic farmers almost unanimously refused to solve their marketing problems by suspending continued conversion. Instead, they wanted to control sales "from field to table." However, when asked how this could be done, they were divided. Both solutions that most respondents preferred require cooperation with conventional firms. Most emphasized both organic and conventional firms, but nearly as many preferred closer collaboration with conventional firms only.

Table 1. Organic farmers' motivations for conversion (%, n=262).[1]

Environmental considerations	66.0
Disagree with developments in conventional agriculture	27.9
Better agricultural products	24.0
Consideration for animals	16.8
Agricultural challenge	13.7
Better earning prospects	9.9
This is the future for agriculture in Denmark	9.5
Consideration for own working environment	8.8
Other	11.8
Two motivations	88.4

[1] Respondents were asked to choose the two most important motivations.

Data from Jensen's survey (1992), analyzed in Michelsen (1994).

Table 2. Organic farmers' attitudes towards suggestions for increasing sales.[1]

Concentrate on production to the greatest possible extent and leave sales to other people	20.8
Control the product "from field to table"	50.4
Aim for closer cooperation with conventional firms in sale of organic products	39.7
Ensure it is always possible to sell to organic firms as well as conventional ones	49.3
Develop sales smoothly and evenly through own organic sales undertakings	21.3
Work for more conversions to get sales really moving	58.4
Stop conversions so that sales can compete	–62.2
Invest more in stimulating sales	43.5

[1] Expressed as Percentage Difference Index (PDI). The replies were categorized as follows: agree; partly agree; partly disagree; completely disagree; neither agree nor disagree; and don't know. The PDI is calculated as follows: (proportion agreeing + proportion partly agreeing) – (proportion partly disagreeing + proportion completely disagreeing). The resulting figure shows how many more agreed with each statement than disagreed with it. A negative value indicates that more disagreed than agreed.

Data from survey by Jensen (1992), analyzed in Michelsen (1994).

Farmers' ambivalence became clearer when they were asked about the consequences of the two solutions. Only small majorities were willing either to let others take responsibility for marketing—as is generally true in conventional firms—or to develop sales even in firms run by the organic farmers themselves. As shown below, their ambivalence led to a third solution: the marketing organizations developed into a multitude of small producer organizations, each of which is closely connected to one or more organic or conventional manufacturers or distributors.

Public Support

A major political debate on the environmental problems of agriculture took place in Denmark in the middle 1980s (Garrido and Moyano, 1994). Plans for solving the problems of discharge of nitrogen, phosphorus, and organic substances were made in 1985 and 1986, partly against the wishes of the conventional farmers' unions. The aim of the process was to make agriculture more ecofriendly. It also paved the way for a publicly financed pilot program for organic farming.

The pilot program lasted 5 years, with its course closely followed by a board of representatives from organic and conventional farmers' organizations, consumer organizations, and public authorities. The program had three main elements. The first was to subsidize farmers' extra expenses during the two years of conversion. After conversion, farmers had to rely on consumers' willingness to pay premiums. The second element eased the marketing process by enacting rules of primary production, processing and distribution modeled after those of the International Federation of Organic Agriculture Movements. Enforcement of the rules was left to a Directorate in the Ministry of Agriculture that certifies producers and inspects their adherence to organic practices. The certification is marked with a special label (the "Ø" label — Ø being the first letter in the Danish word for organic).

The third element of the organic pilot program covered the costs of research and development. Subsidies were paid for producing and disseminating information about organic concepts and products to farmers, consumers, and agents in the food market. This involved collecting systematic information on farmers' production experiences and establishing the specialized advisory system mentioned above. The State subsidized the establishment of nationwide producer organizations within individual sectors, such as milk, vegetables and cereals, to coordinate primary production and collect and market primary products. Information to consumers and market agents covered the expense of general market analyses and advertising campaigns for the Ø label and the general merits of the production concept. Finally, individual firms gained some financial support for developing specific products and marketing activities.

Research and development expenses were very important in the pilot program. Of total public expenditures in the 5-year period amounting to DKK 142 million (about $22 million), one-third was paid as conversion subsidies, with the remaining two-thirds allocated to research and development activities as follows (Danish Ministry of Agriculture, 1993):

Collecting, manufacturing and marketing of products:	18%
Information and training:	21%
Advisory services to farmers:	14%
Research and testing:	47%

The Danish state thus not only contributed to the major expansion in conversion and thereby in supply, but also to several aspects of the marketing process. One direct effect of the pilot scheme was that in August 1990, 45% of Danish consumers knew about the banning of both pesticides and artificial fertilizer in organic agriculture. Other aspects had not gained comparable attention, but only 3% claimed there was no real difference between organic and conventional agriculture, and 23% knew about the Ø label, which was introduced only a short time before (Bjerke, 1992, pp. 78, 221). A second effect was that the supermarkets gained sales experience, which formed the basis for framing a general guide for promoting organic products. A third was that farmers nationwide organized for the sale of products. Some of these organizations played a vital though temporary role in developing contacts with conventional commercial partners.

An evaluation of the pilot program was positive, despite major problems in penetrating the market (Danish Ministry of Agriculture, 1992). The program had contributed significantly to encouraging and developing organic agriculture, whereas direct effects on total volume, exports, employment, or investments were nearly absent. The positive effects were more indirect, and concerned the technical upgrading and professionalization of farmers. However, they were viewed as a positive basis for further initiatives, with special attention to marketing. Against this background, and because of a still more positive political evaluation of organic farming as a type of sustainable agriculture, the pilot program has now become permanent, with largely the same subsidies. However, the subsidies paid to farmers were raised to about half the total expenditure, including a small payment to farmers for continuing with organic practices. This has paved the way for reducing the premiums demanded from buyers, and thus from consumers.

In sum, public support has created a basis from which organic production is now developing an improved though still marginal market position. Increased production has been obtained through subsidies to farmers; the organic qualities of the products are guaranteed by the State; and public support has made it possible to test serious attempts to reach ordinary consumers. These initiatives are necessary for lasting success in the Danish food market, but do not guarantee it. The fundamental distribution problems still must be solved in practice.

Support from Participants in the Conventional Food Market

The primary interest of organic farmers, the organic organizations, and the public authorities was to define organic production methods. Together they formulated a precise production concept. However, they failed to formulate any distinctive marketing concepts, apparently because the market was supposed to develop automatically. The marketing process, so important to the economic survival of organic agriculture, was left to chance.

In 1980, when Danish organic agriculture began to increase, the marketing opportunities seemed good. Sales were expanding both directly and through health shops, and sales soon began through supermarkets. The directors of the largest Danish supermarket concern, FDB, reacted positively to a direct contact from a leading producer of organic vegetables. FDB is the national consumer cooperative movement, supplying more than 30% of the Danish food market through six supermarket chains. FDB's interest was to profile its total concern for consumers' seemingly growing interest in questions concerning nutrition and the environment, because of what FDB has since called its "obligations as a cooperative consumer organization" (stated by Torben Laursen at a conference organized by the Danish Ministry of Agriculture in September 1993).

FDB began to distribute organic vegetables to a few of its supermarkets as early as 1981. Volume was low: less than 0.1% of the sales of any product was organic. However, sales grew slowly but steadily. FDB was very patient in not objecting to the much higher prices and poorer quality of organic products. For example, on the scale employed for conventional products (emphasizing appearance), organic potatoes and vegetables were classified as second class, and organic meat was very variable in color, tenderness and fattiness. FDB even followed up on sales with vigorous informative marketing endeavors and contributed directly to the formulation of public directives on how to process and distribute organic products. Furthermore, FDB tried continuously to offer a wider selection. Soon cereals were included, with milk and meat following in 1988–89.

FDB did not remain the only supplier of organic products among Danish conventional supermarkets. Both its main supermarket competitor (Dansk Supermarked) and a high price, high quality, regional supermarket chain (Irma) began distributing organic vegetables in 1986 (Bech Jensen and Michelsen, 1990). At a time when an increase in the supply of organic products was a foreseeable consequence of public support for conversion, the scope for expanding sales through supermarkets seemed promising.

However, the fundamental distribution problems remained unsolved. This was one result of the supermarkets' patience. The problems were greater in supplies of vegetables (and later of meat) to FDB. Growers only arranged voluntarily and from day to day who should deliver what quantities and where. There were no contractual obligations to guarantee deliveries, and FDB itself had to take care of processing and further distribution of the small quantities. Other conventional retailers signed contracts with small, specialized organic wholesalers or processing firms for vegetables or meat, but in reality their situation was similar to FDB's. This loose distribution structure implied that no one had the obligation or the ability to guarantee organic products to meet the basic needs of any supermarket chain (Kotler, 1991, p. 164):

- adequate delivery guarantees;
- sufficient (i.e., stable and large) quantities of products;
- adequate (and uniform) quality;
- acceptable prices.

Strengthening the Distribution Structure

For vegetables, the effect of the loose structure is reflected in FDB's sales account: a sharp increase from 30 to 2,200 (metric) tons was reported from 1981–82 to 1987–88. Reports for the next two years are missing, but in both 1991 and 1992 FDB only sold about 1,400 tons. In 1993, however, sales expanded to 2,500 tons, and in 1994 was about 3,000 tons (Økologisk Landscenter, 1994, p. 55, and personal communication from Poul Henrik Hedeboe, coordinator of FDB suppliers, September 1993). There was a real danger that FDB would be lost as a faithful partner with major market potential between 1988 and 1992. That the distribution structure is important in this process is seen in the fact that the main change in trading conditions between 1987–88 and 1993 was in how distribution was organized. Only a few closely collaborating growers are now allowed to deliver products to FDB, with the trade based on a detailed agreement with mutual obligations governed by close contacts between FDB and a single representative of the growers. These contractual changes apparently were necessary for the recent growth of sales. This is confirmed by the case of meat, where it was impossible to tighten the distribution structure in a similar way; FDB eventually abandoned systematic sales of meat in 1990.

The need for a stronger distribution structure is illustrated by another example concerning organic vegetables. These were introduced in the high price, high quality supermarket chain Irma in 1986, but sales remained very low until 1989. Then a small private wholesaler specializing in organic vegetables began presenting the products in a way similar to the conventional ones, and reduced prices slightly (Bech Jensen and Michelsen, 1990). The positive effect on sales was so impressive that all Danish supermarkets immediately tightened their quality demands. Since then, organic potatoes and other vegetables have been marketed in supermarkets as first quality products, washed and wrapped in transparent packaging.

The Irma example can be carried even further. The private supplier could not finance the activities needed to maintain the level of service. Supplies in 1993 were taken over by a firm owned by the farmers and run by a professional dealer. This firm has been so reliable in guaranteeing deliveries and quality that all carrots marketed by Irma are now organic. Distribution costs decreased sharply in consequence.

The development of systems to deliver organic vegetables to supermarkets represents one extreme in which organic growers could

retain their initial dominant position in sales. For other products, farmers' influence has become more modest. The extreme case is fluid milk.

The Case of Fluid Milk

In 1988, three groups of newly converted milk producers contacted two of the smallest private dairies in Denmark and the largest, MD Foods (a cooperative of conventional milk producers supplying about 60% of the domestic market). These dairies were encouraged by FDB's steady demand for organic products. MD Foods was FDB's sole supplier of fluid milk products and wished to remain so, although the range of products had expanded to include organic products. All three groups began manufacturing organic fluid milk, but FDB's demand exceeded the capacity of MD Foods. Therefore, MD Foods felt a need to make an agreement with the small organic dairies, for whom the agreement implied a favorable entry to a well-functioning distribution system. But the collaboration was only temporary, since MD Foods also persuaded conventional milk producers to convert by guaranteeing a three-year price premium of 40% over conventional milk.

MD Foods succeeded in attracting milk producers, and collaboration with the small dairies collapsed in 1992. The small dairies, in consequence, were excluded from supermarket sales. Their survival was threatened since they almost could not pay the milk producers any premium at all. One small dairy with 10 to 12 milk producers did survive, however, because the producers accepted lower prices to be independent of the large conventional milk concerns. In 1991–92 the producer price differential ranged from a conventional price of DKK 2.62/kg (1 DKK = $0.16) to DKK 2.79 in the small dairy and DKK 3.65 in MD Foods, which covered 92 organic milk producers (Mejeristatistik, 1992/93; Økologisk Landscenter, 1993, p. 32).

The question of independence even affected the organic milk producers who supplied MD Foods. Because of low and stagnant sales (of the organic milk that MD bought, only one-third was sold as organic in 1992), MD Foods demanded a lowering of premiums in 1993. The milk producers would accept a price reduction only if they gained influence over the concern's processing and marketing practices. They suspected that MD Foods, as a cooperative of conventional farmers, was not making sufficient efforts to sell organic products. The milk producers supplying MD Foods had formed a producer organization and were even prepared to withdraw collectively from MD Foods to join a small, conventional dairy cooperative that could only offer lower premiums.

The conflict was settled in June 1994. The milk producers apparently gained all their demands: a minor cut in price and an influence in production and marketing. MD Foods seems to have accepted these conditions because sales in 1994 were growing at such a rate that problems in 1995–96 could be foreseen if supplies were not increased (Michelsen, 1994). In fact, demand has exceeded supply since the beginning of 1995, and a market analysis by the Federation of Danish Dairies indicates a likely domestic market share for organic fluid milk of about 15% in 1998 (Økologisk Jordbrug, January 1995).

Producer Organizations

Participants in the conventional market have thus granted the organic farmers access to the supermarkets, but it has been necessary to make changes in the products to adapt them to the demands of this channel. The main conventional distributor has been patient, allowing time for a process during which farmers reduced their economic expectations, improved their professional skills, and made organizational changes to solve the distribution problems arising because organic production is small and widely dispersed. This produced the prerequisites for the recent market success.

Today, small producer organizations are the backbone of distribution to supermarkets. The primary objective of the producer organizations is to serve specific distributors or supermarket chains. Most of them also coordinate or cooperate with organic producer organizations related to other (even competing) distributors. In this way, organic farmers have remained cohesive in relation to conventional farmers and the conventional food firms despite their close collaboration.

Danish Consumer Demand

Danish consumers seem to have gone "green" since the late 1970s, both in attitudes and in declared willingness to change consumption habits. In a survey done in 1986, about 30% of Danish consumers declared their willingness to buy organic food and pay a premium of about 25% (Danish Ministry of Agriculture, 1986, Annex 4, p. 4). In 1990–91, opinion polls showed a similar picture: 42% were prepared to pay an unspecified premium for organic products (Bjerke, 1992, p. 95; Kristensen and Grunert, 1992). In a poll taken in June 1994, the fraction of consumers who would pay an unspecified premium increased to 56%, with 76% willing to buy organic products if there was no difference in prices at all (Økologisk Jordbrug, August 1994). In all cases, however, the market shares of organic products were very low: about 1–2% in 1990–91 and about 3–4% in 1994.

In 1990, a major reason was detected for the difference between consumer attitudes and their buying behavior: about 30% of all consumers bought organic products *occasionally*, whereas only 1.5% were *consistent* buyers (Bjerke, 1992, p. 8; Kristensen and Grunert, 1992). A simulated price experiment with 292 Danish consumers in 1991 showed an increase in market share of 1% for potatoes and 0.2–0.5% for tomatoes and fluid milk per 1% reduction in premiums over conventional products (Kirkeby Hansen and Sørensen, 1993). However, the report stressed that price reductions must be publicized heavily in the stores, because most consumers have little knowledge of prices and do not make direct price comparisons when deciding whether to choose organic products. Also, the results were obtained in three supermarkets with several years' experience in marketing organic products. Therefore, they do not contradict the argument made above that successful marketing depends on smooth organization of supplies.

The recent success in marketing organic products seems to meet all the requirements mentioned above. The growth of sales was triggered by an FDB supermarket chain that publicized a modest price cut (15–20%) as part of a so-called "green discount" campaign. The campaign was so successful that prices of organic products were headline news in all the media for several days. The effect of the initial campaign has been sustained, as sales of organic products were still rising nearly two years later. It seems important that the campaign met not only the price requirements but also the organiza-

tional requirements. It was launched by a highly experienced supermarket chain, which had taken the time to build up a reliable distribution system, partly in collaboration with the organic farmers.

Reductions in consumer prices have only reduced, but not abolished, the price differences between organic and conventional products. If a limit for price premiums is set at 30%, 17% of organic products were below this in 1991, whereas the share was 40% after the introduction of "green discounts" (Økologisk Jordbrug, December 1993). For fluid milk, consumer price premiums fell from 71 to 54%, and for potatoes from 52 to 25%, while carrots are an example of price increases since 1991: premiums rose from 27 to 52%. Concerning the campaign's effects on farmers, we know only the positive effects on quantities, but not the extent to which reductions in consumer prices were converted to reductions in prices paid to farmers, except the facts about milk mentioned above.

Conclusions

The "greening" of Danish consumers has recently been used to the advantage of organic products and farming, even more than in other countries. This success was the result of long-term collaboration between organic farmers, public agencies, and conventional manufacturers, distributors and retailers. The effect was threefold: a sharp increase in production; a tight distribution structure in which small organic producer organizations committed themselves to supplying conventional supermarkets, if necessary, through partnerships with conventional manufacturers and distributors; and prospects for stable and steady sales growth under conditions acceptable to both consumers and organic farmers.

The main problem was to solve the fundamental distribution problem stemming from the small number of organic farmers, with their limited production and their dispersal throughout the country, in contrast to the highly centralized Danish food market. The distribution problem was solved by simultaneous developments among farmers, in the regulatory system, and among food firms.

Despite major differences in attitudes toward agriculture, there is no clear separation between organic farmers and their conventional colleagues. They cooperate through farmers' unions, which are connected with the well developed and subsidized Danish advisory systems. Organic farmers preserve their own organic associations, even though they no longer must be members to be certified for organic production. Organic farmers even have collaborated with agricultural cooperatives dominated by conventional farmers by developing an additional system of small producer organizations. The organic farmers have thereby adapted to workings of the conventional food market, which is so important for their economic survival, without abandoning their critical attitude toward conventional agriculture.

As part of the general political debate on agriculture and the environment, the State has contributed to the growth in supply of organic products by subsidizing conversion, certification and inspection, and by research and development, including general marketing efforts directed toward the conventional food market. The conventional food sector, especially the largest Danish supermarket company, has contributed by a steady and patient demand for organic products to develop a "green" profile to match the "greening" of consumers. A comparison of the development of the organic market in Denmark with other countries suggests that both subsidies and the support of market participants are indispensable in developing organic agriculture into more than a marginal or sectarian position in the country's agriculture.

The Danish development of organic agriculture can be described by distinguishing three stages in which different participants predominated. Until 1987, pioneering farmers with nearly no relation to conventional agriculture were predominant. From 1987 to 1992–93, developments were promoted mainly by State subsidies, which institutionalized the field and associated it with the organizational systems of conventional food production and consumption. The recent market success indicates a third stage, in which market processes have become strong enough to dominate. However, state subsidies and farmer involvement (although based on critical attitudes toward conventional agriculture) will still be needed to continue the positive development.

I have concentrated on distribution to supermarkets. Also important is that the growth in Danish organic food production has produced many smaller sales initiatives parallel to this mainstream. They include developing manufactured food products from organic raw materials and access to certain catering opportunities, such as restaurants and meals for clients and employees in day nurseries, kindergartens, canteens, and other organizations.

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References

1. Bager, T., and V. Søgaard. 1994. Landmanden og miljøet. (The farmer and the environment). South Jutland University Centre, Esbjerg, Denmark.
2. Bech Jensen, G., and J. Michelsen. 1990. Samarbejde om afsætning af økologiske og biodynamiske grøntsager. (Collaboration on sales of organic vegetables). Notat 19/90, Institute of Social and Industrial Development, Cooperative Research, South Jutland University Centre, Esbjerg, Denmark.
3. Beus C.E., and R.E. Dunlap. 1991. Assessing alternative vs. conventional agricultural paradigms: A proposed scale. Rural Sociology 56:432–460.
4. Beus C.E., and R.E. Dunlap. 1993. Agricultural policy debates: Examining the alternative and conventional perspectives. Amer. J. Alternative Agric. 8:98–106.
5. Bjerke, F. 1992. Forbrugernes interesse for økologiske produkter. (Consumer interest in organic products). National Economics and Planning, Roskilde University Centre, Denmark.
6. Danish Ministry of Agriculture. 1986. Redegørelse om økologisk jordbrug. (Memorandum on organic farming). Copenhagen.
7. Danish Ministry of Agriculture. 1992. Evaluering af lov nr. 363 af 10. juni 1987 om økologisk jordbrugsproduktion. (Evaluation of the act on organic farming). Copenhagen.
8. Danish Ministry of Agriculture. 1993. Lovforslag L 190. (Bill L 190). Copenhagen.
9. Garrido, F., and E. Moyano. 1994. EC and National Regulations on Environment and Agriculture in Denmark, the Netherlands and Spain. Report 1. South Jutland University Centre, Esbjerg, Denmark.

10. Hecq, W., and A. Vaessen (eds). 1994. Le Marché des Produits de l'Agriculture Biologique dans l'Union Européenne. Les actes du colloque. Association Universitaire pour l'Environnement, and Coopération, Recherche et Animation du Brabannt Wallon de l'Est, Brussels and Jodoigne, Belgium.
11. Jensen, E. 1992. Økologiske jordbrugere og afsætningen af deres produkter—en spørgeskemaundersøgelse. (Organic farmers and the sales of their products—a survey). Notat 28/92, Institute of Social and Industrial Development, Cooperative Research, South Jutland University Centre, Esbjerg, Denmark.
12. Kirkeby Hansen, J., and H. C. Sørensen. 1993. The importance of price for the sale of ecological products. MAPP Working Paper No. 13. Aarhus School of Business, Aarhus, Denmark.
13. Kotler, P. 1991. Marketing Management. Analysis, Planning, Implementation, and Control. 7th ed. Prentice Hall, Englewood Cliffs, N.J.
14. Kristensen, K., and S. Grunert. 1992. Den danske forbruger og økologiske fødevarer. (The Danish Consumer and Organic Products). Series H nr. 62. Institute for Information Processing, Aarhus School of Business, Aarhus, Denmark.
15. Lampkin, N.H., and S. Padel (eds). 1994. The Economics of Organic Farming: An International Perspective. CAB International, Wallingford, England.
16. Mejeristatistik 1992/93. (Dairy Statistics). Federation of Danish Dairies, Aarhus, Denmark.
17. Michelsen, J. 1994. De økologiske jordbrugere og afsætningen. (Organic farmers and sales). Tidsskrift for Landøkonomi (J. Agric. Economics) 181:193–207. Denmark.
18. Økologisk Jordbrug (Journal of organic farming). (various years). Landsforeningen Økologisk Jordbrug, Aarhus, Denmark.
19. Økologisk Landscenter. 1993. Økoguide. Aarhus, Denmark.
20. Plantedirektoratet. 1992. Rapport 1991, om autorisation og produktion på økologiske jordbrug. (Report on certification and production on organic holdings in 1991). Copenhagen.
21. Plantedirektoratet. 1993. Rapport 1992, om autorisation og produktion på økologiske jordbrug. (Report on certification and production on organic holdings in 1992). Copenhagen.
22. Plantedirektoratet. 1995. Autorisation og produktion på økologiske jordbrug 1993 og 1994. (Certification and production on organic holdings in 1993 and 1994). Copenhagen.

UPCOMING EVENTS

June 17-19, 22, 23, (New York/New Jersey off-campus session) and **June 20-22,** (Rutgers University on-campus session), "Paved to Protected: Restoration in the Urban/Rural Context" will be the topic of the Society for Ecological Restoration's 1996 Annual Conference; contact the Society, 1207 Seminole Highway, Suite B, Madison, WI 53711; (608) 262-9547; e-mail ser@vms2.macc.wisc.edu

June 20-22, "Cultivating Community Success" will be held in Lincoln, NE; contact Heartland Center for Leadership Development, 941 O St., #920, Lincoln, NE 68508; 1-800-927-1115.

June 21-22, "AgTech '96," a demonstration of farming technology, will be held on the Davis campus of the University of California; contact Nancy Muller, (916) 754-9883.

June 23-26, 3rd International Conference on Precision Agriculture will be held in Bloomington/Minneapolis, MN; contact Gene Anderson, Program Director, Precision Agriculture Center, College of Agricultural, Food, and Environmental Sciences, University of Minnesota, 1-800-367-5363 or (612) 625-7084; e-mail eanderson@mes.umn.edu

June 24-August 16, "Sustainable Agriculture: Principles and Practices," a summer course, will be held at the Student Experimental Farm, University of California, Davis; contact Mark Van Horn at the Farm, Department of Agronomy, University of California, Davis, CA 95616; (916) 752-7645.

June 28-30, The E.F. Schumacher Society's Decentralist Conference will be held in Williamstown, MA; contact the Society, 140 Jug End Road, Great Barrington, MA 01230; (413) 528-1737; e-mail efssociety@aol.com

June 28-July 2, the 17th Annual Conference of the Hydroponic Society of America will be held in San Jose, CA; contact HSA, 2819 Crow Canyon Rd., #218, San Ramon, CA 94583; (510) 743-9605; e-mail hydrosocam@aol.com

June 29, "Preserving Your Part of the Global Herd," a workshop on the genetic management of horse and donkey breeds, will be held in Lexington, KY; contact Carolyn Christman or Don Bixby, American Livestock Breeds Conservancy, P.O. Box 477, Pittsboro, N.C. 27312; (919) 542-5704.

July 7-10, "Rocky Mountain Rendezvous," the 51st Annual Conference of the Soil and Water Conservation Society, will be held at the Keystone Resort, CO; contact the Society at 1-800-843-7645.

July 8-11, "New Crops, New Products, New Opportunities," the First Australian New Crops Conference, will be held at the University of Queensland, Australia; contact Sally Brown, New Crops Conference Secretariat, University of Queensland, Brisbane, 4072 Australia; phone +61-7-3365-6360; e-mail sally@ceu.uq.oz.au

August 10-13, First Organic World Exhibition will be held in Copenhagen, Denmark; contact IFOAM '96, Blegdamsvej 4, DK-2200 Copenhagen N, Denmark; phone +45-35-37-20-96.

August 19-23, Ecological Summit '96 will be held in Copenhagen, Denmark; contact Ecological Summit '96, Conference Secretariat, Elsevier Science Ltd., The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, United Kingdom; phone +44 (0) 1865 843643; e-mail g.spear@elsevier.co.uk

August 25-31, Symposium on Artificial Rearing of Insect Parasitoids and Predators, the 20th International Congress of Entomology, will be held in Florence, Italy; contact Pat Greany, USDA-ARS, 1700 SW 23rd Dr., Gainesville, FL 32608; (904) 374-5763; e-mail pgreany@nervm.nerdc.ufl.edu

August 26-30, 9th Conference of the International Soil Conservation Organization will be held in Bonn, Germany; contact A. Klein, Federal Environmental Agency, FG 11 3.2/Soil Quality, P.O. Box 330022, D-14191 Berlin, Germany; e-mail 100434.1121@compuserve.com

Evaluating the sustainability of alternative farming systems: A case study

John Ikerd, Gary Devino, and Suthijit Traiyongwanich

Abstract. *The sustainability of farming systems must be assessed by their potential environmental, economic, and social performance. We present a case study to illustrate an assessment of relative sustainability that uses all three performance criteria.*

We developed two scenarios for farmland currently enrolled in the Conservation Reserve Program (CRP) in Putnam County, Missouri: a conventional scenario reflecting farming practices typical of northern Missouri, and an alternative that we hypothesize to be more environmentally sound. We used selected economic and social indicators to assess whether the latter would be at least as economically viable and socially responsible as the conventional system.

Estimated direct farm income was $3.4 million for the alternative and $2.4 million for the conventional scenario. The alternative system applies more labor and management to a given land resource and may support more farming families. Estimated total community economic impacts were 25% greater for the alternative than the conventional farming scenario. CRP land, therefore, could be returned to production in a way that could significantly enhance local economic and social benefits while retaining many of the CRP's environmental benefits.

Key words: Missouri, Conservation Reserve Program, sustainable agriculture, intensive grazing, local economic impacts

The term *sustainable agriculture* has many definitions (Altieri, 1988; Lockeretz, 1988; Allen et. al., 1991). However, most refer to the performance of a farming system without specifying farming practices, methods, or enterprises. The Food, Agriculture, Conservation, and Trade Act of 1990 defines sustainable agriculture for purposes of federally funded research and education programs as "integrated systems of plant and animal production practices having site specific application that will over the long run: (a) satisfy human food and fiber needs, (b) enhance environmental quality and the natural resource base upon which the agricultural economy depends, (c) make the most efficient use of nonrenewable resources and on-farm resources, and integrate, where appropriate, natural biological cycles and controls, (d) sustain the economic viability of farm operations, and (e) enhance the quality of life for farmers and society as a whole" (U.S. Congress, 1990a).

Discussions during the legislative process further clarified the intended meaning of quality of life. Indicators of enhanced quality of life included increased income and employment opportunities in agricultural and rural communities, especially self-employment opportunities, and an agricultural system based on small and moderate-sized family farms, principally owner-operated (U.S. Congress, 1990b).

Most definitions and the above legislation agree that a sustainable agriculture must be environmentally sound, economically viable, and socially responsible. There is far less agreement concerning the appropriate criteria and indicators needed to measure progress toward these multiple objectives.

An agriculture that meets all three objectives of sustainability can maintain its productivity and value to human society over time, and thus could make a critical contribution to a sustainable society. Sustainability of life on earth depends on a perpetual infusion of energy, specifically solar energy, to offset the degradation of energy and matter associated with the fundamental life processes. A system that degrades energy less rapidly than it captures solar energy can be sustainable indefinitely. An agricultural system that fails to meet one of the three objectives of sustainability cannot be sustained over time without degrading the sustainability of the larger systems of which it is a part (Ikerd, 1994).

One cannot prove empirically that one agricultural system is sustainable and another is not. Such a conclusion requires certainty concerning the future, but the future is inherently uncertain. One can only conclude that according to current knowledge, a system is likely or unlikely to be sustainable. Even the distributions of future possibilities are uncertain, which precludes our accurately assessing the probability of long-term sustainability. Attempts to assign specific probabilities to future events may be futile, even where the fundamental nature of such risks are clear. For example, it may seem obvious that rapid depletion of fossil fuel reserves represents a significant risk to long-term sustainability. However, it is impossible to assess accurately the probability that total energy reserves will drop below some critical level at any specific time. One cannot know what alternative fuel sources might be discovered or what alternative technologies, including solar conversion technologies, might be discovered meanwhile.

Similar assertions may be made regarding often-used criteria for agricultural

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sustainability such as soil erosion, water quality, farm profitability, or viability of family farms and rural communities. Relationships between such criteria and agricultural sustainability are neither certain nor probabilistic. Thus, criteria for and indicators of sustainability must be selected through logical deduction rather than empirical observation. In assessing sustainability, one can only ask whether the system is environmentally sound, economically viable, and socially responsible. All three are necessary, but none is sufficient by itself. Logical criteria and indicators must be chosen on a case by case basis. However, answers to these fundamental questions can never be certain and are rarely clear.

Sustainability of a system may be measured using indicators for each criterion selected for evaluation. Some representative criteria for evaluating sustainability are shown in Table 1. Obviously, one cannot evaluate the full range of logical criteria and indicators of sustainability. However, explicit consideration should be given to all three dimensions of sustainability: environmental, economic and social. A study may emphasize one of these, but any study of sustainability should give some attention to all three.

Table 1. Examples of evaluation criteria for sustainability.

Environmental
Surface and ground water quality
Soil and water conservation
Energy efficiency
Farm safety
Biological diversity
Food safety
Economic
Economic competitiveness or costs
Farm profitability
Return on investment
Income variability
Financial risks
Food costs
Social
Availability and quality of food and fiber
Employment opportunities
Rural landscapes
Self esteem of farmers
Ethics of farm practice
Self-perceived quality of life

A system judged superior in one or more of the three dimensions, and not inferior in any other, may be judged more likely to be sustainable. Ordinal, qualitative measures of sustainability are adequate to draw conclusions in such cases. Where one system is judged superior in at least one dimension but inferior in another, its advantages must be weighed against its disadvantages. Conclusions in such cases require quantitative or interval-scale indicators that can be aggregated within each dimension and then compared across dimensions.

Research on Impacts of Sustainable Agriculture Systems

Previous studies of the relationship between agricultural practices and sustainability either failed to consider all three criteria or were inconclusive. For example, Lockeretz (1989) compared the local economic impacts of high input conventional cropping systems and lower input alternatives. The underlying assumption was that the lower input systems were more environmentally sound. Thus, lower input systems would contribute more to sustainability than the conventional ones if they contributed at least as much to the economic viability of the local community. The results of five regional comparisons were inconclusive on this point.

Lockeretz (1989) found that the lower input systems generally contributed less per acre to the local economy than did the higher input systems, resulting in a conflict between the relative economic and environmental performance of the two types of cropping systems. He did not attempt to assess quality of life or social indicators such as farm size, self-employment, or viability of family farms in the local community.

A South Dakota study (Dobbs and Cole, 1992) went beyond this work in evaluating the impacts of alternative farming systems on consumer spending and marketing services in addition to business spending for production inputs. The study paired five farms classified as "sustainable" with five "conventional" farms representing various regions of South Dakota. Data for the "sustainable" farms were obtained from on-farm interviews, but four of the five "conventional" farms were synthesized from various sources. The "sustainable" farmers were almost organic in that none used inorganic fertilizer and only one reported appreciable use of commercial pesticides.

First-round economic impacts on local input purchases and marketing services clearly were negative for the "sustainable" farms. Not only did they purchase fewer inputs and sell less per acre; they also purchased more of their inputs and sold more of their products outside the local community. First-round effect on farm household income clearly depended on whether organic premiums were included. Without premiums, four of the five "conventional" farms produced more income per acre, but with premiums, three of the five "sustainable" farms were higher. Induced economic impacts, that is, the income impacts of subsequent consumer spending, simply magnified the differences found among farm household effects.

Despite these conclusions, the South Dakota results were inconclusive regarding agricultural "sustainability." The assumption, explicit in this case, was that the "sustainable" farms were more environmentally sound than the conventional farms. However, sustainability requires that such farms also be economically viable and socially responsible. Two of the five "sustainable" farms clearly were not more economically viable than the conventional farms, according to the economic data presented. In pairs where one farm was more environmentally sound and the other more economically viable, no conclusions could be drawn regarding their comparative sustainability.

With organic premiums, three of the five "sustainable" farms appeared more economically viable than their conventional counterparts and contributed as much or more to the community. The authors questioned the sustainability of organic premiums, which also puts in doubt the sustainability of organic farming. However, their more serious problem in drawing conclusions regarding sustainability is that their study omitted the quality of life or social dimension of sustainability, such as differences in size between conventional and sustainable farms.

A Case Study of Sustainability

The study reported here was developed to evaluate the relative sustainability of two production systems for land currently in the

Conservation Reserve Program (CRP) in Putnam County in northern Missouri, a county with high CRP participation (26,000 acres). The conventional scenario reflects farming methods typical of northern Missouri farms. The alternative scenario was designed to achieve a balance of environmental, economic and social benefits. It assumes increased use of crop rotations, more intensive management of inputs and reduced tillage methods for cropping, and intensively managed pasture-based beef production. We attempted to have this system retain as many environmental benefits of the CRP as practical while being more profitable to farmers and more economically supportive of the local community. All farming systems were "synthesized" using secondary data from various sources and the opinions of individuals knowledgeable about farming in the area.

The criteria used for environmental soundness in this study were natural resource conservation, as indicated by soil loss and energy use, and environmental protection, as indicated by agricultural chemical use and cropping diversity. The economic criterion was farm profitability, as indicated by the market value of commodities produced minus direct costs, including purchased inputs for crops and livestock and interest costs associated with livestock ownership. (We have called this difference "direct farm income" to minimize confusion with other measures of profitability.) Criteria for social responsibility used in this study were employment opportunities in the community and use of community resources. Indicators of social responsibility were the potential number of viable family farms and the level of economic activity in the local community.

To simplify the comparison we assumed the same acreages of the same crops under both scenarios, using recent cropping history for the county. However, the continuous corn and soybeans conventionally grown on about half of Putnam County cropland were replaced under the alternative scenario with crop rotations, mostly corn rotated with soybeans. The alternative scenario used ridge tillage in place of conventional tillage on more erodible lands. The ridge tillage system used cultivation and banded input applications, thus cutting herbicide use in half and reducing nitrogen application while maintaining yields and controlling erosion more effectively than conventional tillage.

We set the conventional fertilizer application rates at levels that would not limit yields under the most favorable growing conditions. Fertilizer use for the alternative scenario was reduced for realistic yield goals, allowing loss of yield in the very favorable years. Traiyongwanich (1994) describes in detail the two scenarios, the methods of analysis, and the research supporting the assumptions regarding crop yields and cattle stocking rates.

The alternative farming scenario represents only a modest departure from conventional systems in northern Missouri. For example, sustainable agriculture advocates may view a 50% reduction in commercial herbicide use in corn-soybean rotations as merely a fine tuning of conventional farming. However, the objective of this study was to evaluate alternatives that would be viewed as reasonable, not as radical departures from practices common in the area. We do not claim that the alternative scenario is sustainable, only that it might move farming in the direction of sustainability. Our primary purpose is to outline an appropriate approach to assessing sustainability, rather than to defend the conclusions of this case study.

The alternative system of cattle production was represented by management intensive grazing with 24 paddocks, using data from the Forage Systems Research Center (FSRC) in northern Missouri (Moore, 1994). Conventional livestock production was represented by a three-paddock grazing system, which probably overestimates the intensity of management of typical Putnam County livestock operations. The alternative would allow farmers to stock over 50% more cows than the conventional grazing system on the same amount of land. This assumption is consistent with historical research results at the FSRC (Moore, 1994) and with on-farm experiences of farmers who have adopted this system in northern Missouri.

Differences in Production Costs and Farm Income

Estimated costs and returns per acre were multiplied by the numbers of acres of CRP land to be returned to crop and livestock production in Putnam County, assuming the CRP program expires. A survey of post-CRP intentions of Putnam County CRP contract holders found that 50% of current CRP land would be used for crops and 41% for livestock (Traiyongwanich, 1994).

We computed direct costs of $946 thousand if CRP land is returned to conventional crop production, compared with $707 thousand for the alternative cropping system (Table 2). However, costs for the conventional livestock system were lower, totaling $1.03 million, in comparison with $1.40 million for the alternative system because of the latter's higher stocking rates. Thus, total direct costs were higher for the alternative system: $2.11 million, compared with $1.98 million for the conventional system. Direct farm income was nearly $1 million higher for the alternative system: $3.40 million compared with $2.42 million for the conventional system.

Direct farm income, the sole indicator used for economic viability, includes returns to the farmer's land, labor, capital, and management. The same land was assumed for both scenarios, namely, land currently in the CRP in Putnam County. Interest associated with livestock ownership was included in direct costs to reflect differences in stocking rates per acre. Interest and depreciation of equipment was not included, however. Farmers vary widely in the equipment they have available or that they choose to buy to carry out the same farming practices. Thus, any attempt to include interest and depreciation of equipment could be misleading.

In this study, the differences in direct farm income probably reflect the difference in returns to farmers' owned resources as accurately as any single indicator can. Also, direct farm income is a buffer between costs and returns that allows farmers to continue operating when total costs cannot be covered. Thus, direct farm income is an indicator of short-term profitability and of the resilience necessary for long-term economic viability.

Local Opportunities in Farming

Concerning first round, direct impacts of returning CRP land to production, the alternative scenario could increase local economic opportunities without exposing the land to the full environmental risks of conventional production. Direct farm income is estimated to rise from the current $1.7 million in total annual CRP payments for the county to $3.4 million under the alternative scenario or $2.4 million under

Table 2. Costs and returns for farming scenarios ($1,000).

	Crops	Livestock	Total
Input costs			
Alternative	707	1,401	2,108
Conventional	946	1,031	1,977
Gross Revenue			
Alternative	2,831	2,681	5,512
Conventional	2,630	1,768	4,398
Direct Farm Income			
Alternative	2,124	1,280	3,404
Conventional	1,684	737	2,421

the conventional scenario. The 26,000 acres enrolled in the CRP program theoretically could support twice as many farm families as are currently supported by CRP payments, assuming that a dollar in direct farm income will support as many people as a dollar in CRP payments. In addition, nearly 40% of current CRP payments made to Putnam County landowners go to persons living outside Putnam or any adjoining county, whereas most returns to labor and management would accrue to local farm operators. There is no reason to expect that returns to absentee landlords would rise as local farmers adopt systems that require less land per unit of labor and management to produce an equal or larger output.

These results are similar to those of a Nebraska study that used detailed economic data provided by 28 farmers, half classified as "conventional," the other half as "sustainable" (Kleinschmit et al., 1994). Compared with those called "conventional," the "sustainable" farms had only about one-half as much land, livestock, and total sales. However, the "sustainable" farmers reported a higher average farm income (returns over direct costs per farm) despite their smaller size. A total of 169 people were supported by the 28 farms in the Nebraska survey. An estimated 44 additional people could have been supported on the same land with at least as high a per capita income if all farms in the survey area had been of the same average size as the "sustainable" farms.

Whether the potential for one farming system to support more families than another would be achieved depends on many factors. The "sustainable" farming systems in both this and the Nebraska study used more labor and management per acre of land and per dollar of capital invested. The additional people may or may not be families living and working on smaller, independently owned farms. However, the social indicators of "potential" farm size and ownership structure are like the "potential" soil loss or "potential" water quality risks associated with use of particular cultural practices or chemical inputs on particular soil types. All such measures represent "potential" problems and "potential" benefits that may or may not be realized under actual conditions over any particular period.

Measuring Community Economic Impacts

Total local economic activity, which includes personal income and returns to other local factors of production, was measured with a standard input-output model.

Direct effects

Farming activities have direct, indirect, and induced impacts on the local economy. Direct impacts are the first round impacts associated with purchases of production inputs and sales of farm commodities; we did not include direct farm income as a direct impact in this study. Direct effects were $2.37 million for the alternative and $2.09 million for the conventional scenario.

Indirect effects

Indirect effects result when local farm input suppliers or marketing firms buy raw materials, products, or business services from local sources. Substantial leakages typically occur between direct and indirect economic impacts. A large portion of total production inputs may be purchased from sources outside the local community. Even when items are purchased locally, only a small proportion of the total sale price may be retained by local input suppliers and service providers. Additional indirect effects occur when local suppliers or service providers buy their input materials or services from other local sources. However, additional leakages occur with each round of activity until additional local impacts eventually become negligible.

Sales of farm commodities also can have indirect effects on the marketing, processing, or value-added sector of the local economy. Commodities sold locally generate sales commissions and other income for local marketing firms. Marketing firms may purchase supplies or employ local residents, resulting in indirect economic impacts similar to those associated with input purchases. As with purchases, leakages occur at each round of activity, with subsequent impacts from a given marketing transaction eventually becoming negligible.

Total indirect effects represent the sum of all local economic activity occurring after, but in response to, the initial purchases of inputs or services and the sales of commodities. Indirect impacts are associated with the local business sector, including manufacturing, wholesaling, and business services. Induced impacts, on the other hand, are associated with local consumptive activities. We estimated the indirect effects at $926 thousand for the alternative and $776 thousand for the conventional scenario.

Induced effects

Induced impacts occur when people spend money they earn from participating in the local economy. Obviously, those earning income from agricultural transactions include farmers and farm workers. Thus, direct farm income was included as an induced effect in this study. However, the employees of local input suppliers, marketing firms, and other service providers also earn income from local agricultural transactions. As with indirect impacts, initial consumption expenditures have second, third, and higher round impacts, when employees of local retailers spend part of their incomes for local goods and services, which in turn generates income for local residents who provide those goods and services. Here, too, the impacts of each successive round of consumption eventually become negligible.

We calculated the economic impacts of purchases and consumption expenditures using the estimated production costs and direct

farm income shown in Table 2. Marketing impacts were estimated separately. We made allowances for differences in sales between conventional and alternative systems and for the amount of grain fed to livestock. Total marketing margins were estimated at $139 thousand for the same CRP land returned under the alternative scenario and $110 thousand under the conventional scenario.

Total Economic Impacts

In summary, the total economic impact from returning CRP land to production under the alternative scenario was estimated at $7.86 million: $2.37 million direct effects (excluding direct farm income), $0.93 million indirect effects, and $4.56 million induced effects, including direct farm income (Table 3). This compares with $6.27 million under the conventional farming scenario: $2.09 million direct effects (excluding direct farm income), $0.78 million indirect effects, and $3.41 million induced effects, including direct farm income.

The economic impacts of crop production under the two scenarios were similar, although their impacts on resource conservation and environmental quality would be very different. Most of the economic difference arises from the livestock sector. Production and direct income potential are significantly higher for the intensively managed grazing system. The alternative system generated an estimated 25% more local economic activity than did the conventional system. Most of the $1.59 million advantage for the alternative system is associated with the higher direct farm income and the associated consumption spending in the local economy.

Conclusions

Returning CRP land to production appears more likely to be sustainable under the alternative farming scenario than under the conventional scenario. The alternative farming system is likely to be more environmentally sound because it would require fewer commercial inputs and result in less loss of topsoil. The alternative system also appears economically preferable because of its higher direct farm income, and may be more socially responsible, as indicated by its greater potential for local employment opportunities and economic activity.

Whether current CRP land owners would consider the alternative system more economically viable than the CRP is beyond the scope of this study. Also, current CRP land use practices probably are more environmentally sound and resource conserving than those of either the conventional or alternative scenario. Returning land to production under the alternative scenario would retain more of the CRP's environmental benefits. However, we need to assess the significant trade-offs among environmental, economic, and social impacts when comparing the alternative scenario with the CRP program. Sustainability is a question to which the answer is seldom either definite or clear.

References

1. Allen, P., D. Van Dusen, J. Lundy, and S. Gliessman. 1991. Integrating social, environmental, and economic issues in sustainable agriculture. Amer. J. Alternative Agric. 6:34–39.
2. Altieri, M.A. 1988. Beyond agroecology: Making sustainable agriculture a part of the political agenda. Amer. J. Alternative Agric. 3:142–43.
3. Dobbs, T.L., and J.D. Cole. 1992. Potential effects on rural economies of conversion to sustainable farming systems. Amer. J. Alternative Agric. 7:70–80.
4. Ikerd, J. 1994. Assessing the health of agroecosystems from a socioeconomic perspective. Paper presented at 1st Int. Symposium on Ecosystem Health and Medicine, Ottawa, Ontario, Canada, June 19–23.
5. Kleinschmit, L., D. Ralston, and N. Thompson. 1994. Community impacts of sustainable agriculture in northern Cedar County, Nebraska. Spec. Rept., Center for Rural Affairs, Walthill, Nebraska.
6. Lockeretz, W. 1988. Open questions in sustainable agriculture. Amer. J. Alternative Agric. 3:174–181.
7. Lockeretz, W. 1989. Comparative local economic benefits of conventional and alternative cropping systems. Amer. J. Alternative Agric. 4:75–83.
8. Moore, Kevin C. 1994. Management intensive grazing: A look at the economics. Extension Paper, Dept. of Agricultural Economics, University of Missouri, Columbia.
9. Traiyongwanich, S. 1994. Post–CRP land use alternatives for Putnam County, Missouri. Unpublished Masters Thesis. Dept. of Agric. Economics, Univ. of Missouri, Columbia.
10. U.S. Congress. 1990a. Food, Agriculture, Conservation, and Trade Act of 1990, Public Law 101–624. Washington D.C.
11. U.S. Congress. 1990b. Congressional Record, October 22, 1990: H11128. Washington D.C.

Table 3. Total projected economic impact of utilizing conventional and alternative production practices on post-CRP land, Putnam County, Missouri ($1,000).

	Alternative	Conventional	Difference
Direct	2,368	2,088	281
Indirect	925	776	149
Induced	4,565	3,406	1,159
Total	7,858	6,270	1,589

N.C. Newspaper Wins Pulitzer Prize for Hog Farm Series

The Raleigh *News and Observer* has won journalism's highest honor—the Pulitzer Prize for public service—for its stories about the corporate hog farm industry in North Carolina, and its related health and environmental problems. The newspaper "was recognized for stories that appeared throughout the year revealing how agricultural corporations were replacing small family hog farms with modern complexes, which relied on untested waste disposal systems that polluted the environment and posed major health risks," according to *The New York Times*.

"Citizen groups and their political allies credit the Raleigh newspaper's 'Boss Hog' series for putting the issue on the political agenda," wrote *The Charlotte Observer*. "The series also reenergized efforts for placing a moratorium on new hog farms until tougher environmental rules are in place, and for giving counties zoning control over where hog farms can go."

Comparison of organic and sustainable fed cattle production: A South Dakota case study

Donald C. Taylor, Dillon M. Feuz, and Ming Guan

Abstract. *Organic and sustainable fed cattle production are compared through development and estimation of two production indexes: a Producer Organic Index (POI) and a Producer Sustainability Index (PSI). The POI reflects current production standards for organically certified beef. The PSI reflects a broader range of concerns, including long-term natural resource conservation and economic staying-power of cattle producers.*

The study shows there may be only a loose connection between the two. The method used to develop the indexes can provide insights to beef cattle extension specialists and individual cattle producers on the strengths and weaknesses of current feedlot management practices.

Key words: organic production, sustainable production, beef cattle

This article presents the results of an exploratory comparative study of "organic" and "sustainable" fed cattle production in South Dakota. The study involves development and empirical estimation of two indexes: one designed to reflect organic dimensions of fed cattle production, the other to reflect its broader sustainable dimensions.

An inspiration for this study was the cover story of the Winter 1993 issue of *Organic Farmer: The Digest of Sustainable Agriculture,* which bore the title, "Organic and sustainable: Debate or dialogue?" The cover story drew attention to "changing self-definitions of a changing constituency" concerning the terms "organic" and "sustainable" (Gershuny, 1993, p. 7). To convey the diversity of thinking among farmers and activists in the country, several people were asked to respond to three questions: 1. "What is the difference between organic agriculture and sustainable agriculture?" 2. "Which do you feel more comfortable with?" 3. "What negative associations do you have with either one?" A sampling of responses follows (Organic Farmer, 1993, pp. 14–21).

- The transformative power of these developments [regarding sustainable agriculture] has been limited by corralling organic agriculture into a narrow arena of specialized production and niche marketing, while sustainable agriculture has broadened to include any new initiative in agricultural development, research, and policy. (Forster)
- Organic is used to describe a production system that largely excludes the use of synthetic chemicals. . . . Sustainable agriculture [is] inclusive of other factors . . . pivotal to the long-term success of agriculture. (Wonnacott)
- Organic agriculture is merely one model of sustainability. . . . The producer who qualifies as organic simply because he does not use any "unacceptable" materials to produce his crops, but who does nothing to recycle nutrients or to create a healthy, diverse growing environment to naturally control pests, will find himself mining the soil and wasting resources in a manner that cannot be sustained. Organic agriculture that only seeks to avoid using "unacceptable" materials to qualify for the safe food market cannot be sustained over the long term and does not deserve the label "organic." (Kirschenmann)
- The more organic agriculture focuses on the marketing aspect, the more it loses relevance for the wider challenges for sustainability in agriculture as a whole. . . . I have little comfort with either term since one is too narrow, the other too broad. (Wollan)

Our view is that current standards governing organic beef production are aimed most directly at insuring the health and welfare of animals and producing a differentiated product believed by organic certifying authorities to be more healthful for consumers. We believe that sustainable beef production involves not only these concerns, but also conserving natural resources, maintaining ecological balances, and ensuring the economic survival of food producers. (We do not deal with social, family, community, and other institutional dimensions of sustainability in this article.)

Historical Background

The U.S. government's traditional free-market posture toward regulating cattle production has contrasted strongly with Europe's. In 1990, however, the U.S. took a major step toward developing regulations covering cattle production. We took both European and U.S. regulations into account in developing the two producer indexes.

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Europe

As early as 1911, Great Britain passed the Protection of Animals Act, which delineated various acts of cruelty toward domestic and captive animals. The Agriculture (Miscellaneous Provisions) Act of 1968 is the main legislation applying today to the welfare of animals in Great Britain. Among its other provisions, this act

> 1) makes it an offense to cause unnecessary pain or unnecessary distress to livestock being kept for farming purposes on agricultural land; (2) gives authority for veterinary officers . . . to inspect, on welfare grounds, farms where livestock are being kept; and (3) empowers the appropriate minister to introduce regulations to improve the welfare of livestock. (Ewbank, 1988, p. 6)

In 1976, the Council of Europe passed the European Convention for the Protection of Animals Kept for Farming Purposes. Through this convention, livestock producers are required to meet the "physiological and ethological [behavioral] needs" of farm animals. Physiological needs are expressed in terms of dietary and exercise requirements. Behavioral needs are expressed, among other ways, in terms of five freedoms: "An animal should at least have sufficient freedom of movement to be able without difficulty, to turn round, groom itself, get up, lie down, and stretch its limbs" (Ewbank, 1988, pp. 3–4).

A special case of regulated cattle production involves organic production certification standards. For years, several European countries have had their own individual organic certification standards (e.g., Skal, 1991). In 1992, European Union Regulation 2091/92 set forth broad organic standards for commodities sold in the European Community (Manley, 1994, p. 12). Based on the broad outline of EU Reg 2091/92, detailed animal production standards are now being developed (New Farmer and Grower, 1994, p. 7).

United States

Until recently, the U.S. Department of Agriculture (USDA) exercised little regulation of cattle production. Its primary roles have been to inspect slaughter of cattle, inspect and grade carcasses and finished meat products, and regulate animal drugs and labelling.

The Food, Agriculture, Conservation, and Trade Act of 1990 (FACTA) directs USDA to exert more authority over cattle production. FACTA provides voluntary programs designed to create a more environmentally and economically sustainable livestock production system. The programs include the Integrated Farm Management Option, Integrated Management Systems research, and portions of the Conservation Reserve Program (Wilder, 1991, pp. 3–4).

FACTA also contains the U.S.'s first organic certification title, the Organic Foods Production Act of 1990 (OFPA). This title has three purposes: 1) to establish national standards governing the marketing of organically produced commodities; 2) to assure consumers that organically produced commodities meet a consistent standard; and 3) to facilitate interstate commerce in organic products (OFPA, p. 3935). It called for establishment of a National Organic Standards Board (NOSB) to "assist in the development of standards for substances to be used in organic production and to advise the Secretary on any other aspects of the implementation of the title" (OFPA, p. 3947). As of summer 1995, NOSB had made progress in fulfilling its mandate, but had not yet made final recommendations (USDA, 1995).

In conceiving the research reported here, we gained especially useful insights from Francis Blake, a primary architect of Europe's certification standards for organic agricultural production and marketing, and from the European literature on organic agricultural production. We also decided early in the project to develop not just an index reflecting organic standards, but also one based on a broader set of sustainability criteria. The research reported here is intended to support the NOSB effort in developing U.S. certification standards for organic beef production.

Conceptual Development: Organic And Sustainability Indexes for Fed Cattle

In this section, we discuss the approaches followed for developing both the organic and sustainability indexes for fed cattle production. We then explain the rationale for the specific procedures used in creating each index. Finally, we discuss the significance of contrasting weights given to various practices in the two indexes. A complete treatment of these issues is given in Taylor and Feuz (1993).

Approaches in common for the two indexes

The approach used in developing the producer organic and sustainable indexes (POI and PSI) is patterned after that used by Taylor et al. (1993) in developing a Farmer Sustainability Index (FSI) for 85 cabbage producers in Malaysia. The FSI was designed to reflect the inherent sustainability of 33 management practices. An assumption in both studies is that organic and sustainable production practices are multifaceted, so that they must be assessed on a continuum rather than in a discrete "0–1" format.

With both studies, scores were first assigned to individual production practices, then grouped according to substantive production and natural resource subject areas, and finally combined into a composite score for each producer. As with the FSI, the fed cattle POI and PSI were developed before attention was given to the empirical data-set covering producers' management practices. However, as explained later, the management practices included in the fed cattle POI and PSI were based on questions included in a questionnaire administered in winter 1991–92 in which we solicited information on management practices being followed by South Dakota cattle feeders (Taylor and Feuz, 1993, pp. 64–67). Various management practices were scored according to an appraisal of their inherent organic and sustainable content, according to the following guidelines:

- Positive, 0, and negative scores, respectively, were assigned to individual practices believed to contribute to organic or sustainable production, to be neutral, and to detract from organic or sustainable production.
- Individual practices and different types of practices contributing more to (or detracting more from) the ideal standards of organic or sustainable production were scored higher (in absolute value).

For both the POI and PSI, we gave attention to four types of production practices: feeding, health management, manure management, and drinking water access and

quality. The PSI also covered overall farm and ranch management.

Fed cattle producer organic index (POI)

The U.S. does not yet have official national organic beef certification standards; USDA does not permit livestock products to be labeled as "organically" grown. Thus, the fed cattle POI in this study was based on standards in effect as of June 1993 for the following eight organic certification sources:

1. California Certified Organic Farmers, in its 1993 Certification Handbook (CCOF, 1993)
2. International Federation of Organic Agriculture Movements, in its 1989 standards (IFOAM, 1989) and minutes from the January 30–February 2, 1991 meeting of the Animal Standards Sub-Committee (IFOAM, 1991)
3. National Organic Standards Board Livestock Committee, in a March 1992 report to the NOSB on the results of a mail survey of 252 organic livestock producers (NOSB, 1992)
4. NOSB Livestock Committee, in a statement covering "national standards for organic production" distributed on March 17, 1993 for response by the public (NOSB, 1993)
5. Northern Plains Sustainable Agriculture Society, in its "guiding philosophy" for organic livestock production (NPSAS, 1992)
6. Organic Crop Improvement Association, in its 1993 certification standards (OCIA, 1993)
7. Organic Food Production Act of 1990, in its broad organic certification guidelines (OFPA, 1990)
8. Organic Food Producers Association of North America, in a draft statement by committees of OFPANA and Organic Farmers Association Council (OFAC), June 1, 1992 (OFPANA and OFAC, 1992).

The practices covered by these organic certification sources have direct implications for animal health and welfare and for human health, and involve natural rather than synthetic inputs. Many practices covered in the organic standards are intended to produce differentiated "organically certified beef" that some consumers will perceive as healthier and tastier (even if that perception is not documented scientifically) and for which they will be willing to pay a premium.

In scoring the individual practices in the POI, we gave higher scores if all eight certification sources listed above had established standards for the practice that pointed clearly in the same direction. We assigned positive scores to required and recommended practices and negative scores to prohibited practices.

To illustrate, since all eight sources require the exclusive feeding of organically produced feedstuffs, a high weight was given to this practice in the POI. Since only four of the eight sources have explicit standards on drinking water, practices concerning drinking water access and quality received less weight. Seven of the eight sources recommend cautious use of parasiticides. However, since some organizations provide greater latitude than others on possible use of parasiticides, producers who "regularly" use parasiticides received a negative but only modest score in the POI.

Fed cattle producer sustainability index (PSI)

Two underlying principles were followed in developing the fed cattle PSI. We gave attention to both short- and long-term implications of various production practices for productivity, profitability (both average and year-to-year variability), environmental quality (water and soil resources), animal health and welfare, and human health and safety. Second, high positive scores were assigned to practices strongly recommended to producers by progressive, broad-minded animal and range scientists, veterinarians, and agricultural engineers. At the other extreme, high negative scores were assigned to practices that generally are not recommended to producers.

Two factors prevented us from applying these principles simply and fully. First, we did not have adequate resources to develop both the substantive content of the indexes and questions that could subsequently be asked of producers for real-world verification of the indexes. Rather, the practices that could be included in the indexes and later be used in verifying the indexes were limited to those that had been included in a questionnaire administered before development of the indexes (Taylor and Feuz, 1993, pp. 64–67). If the earlier questionnaire covered some aspect of sustainability in too little detail, we assigned it less weight than it would have merited if full information had been available.

Second, the natural scientists, social scientists and farm producers sometimes had different judgments on the implications of certain production practices for production, profit, the environment, animal health and welfare, and human health and safety. Contrasting views were particularly evident for practices with contradictory implications, depending on one's standpoint. An example is whether producers with low debt-to-asset ratios should be "rewarded" with positive scores because they are less vulnerable to default on their debts, or should be "punished" with negative scores for failing to take advantage of lower per-unit production costs sometimes achievable through economies of scale.

An example of contradictory judgments among well-qualified resource personnel concerned parasiticide use. One commentator said the following:

> Don't even think about a minus value for a rancher who regularly worms and "pours" his cows! It has been shown in trial after trial that regular worming and lice control is a very good and profitable practice. Give a +2 for regular use, a 0 for sometimes, and a –2 for never.

In contrast, another said:

> Use of parasiticides is an important indicator of the balance and sustainability of a system. The best run operations will be using none—as their rotation system, health promotion program, and general management will be so well-honed that they do not need them. Regular use indicates that there is a breakdown in the system, i.e., it is not sustainable biologically. . . . So although many operations may use some, particularly as their systems settle down and achieve balance, I would suggest that regular use should be accorded a high negative score and no use a high positive score.

For practices in which the judgments of various resource personnel diverged (in some cases probably because of site-specific differences), we either assigned modest scores or assumed the practices were neutral in their impact to sustainability.

POI and PSI scores assigned to different practices

In this section, we first illustrate the scoring of selected practices constituting the

POI and PSI. We then present an overview of the weights given to all practices in each index.

1. *Scoring selected feeding practices.* Producers were assigned negative scores if they fed diets in which the proportions of grains exceeded the levels shown in Table 1. Feeding systems varying in the relative importance of grazing and confinement feeding were scored either negatively or positively, as shown in Table 1, according to the following rationale.

For the POI, only one of the eight organic certification sources takes a position on the grain-roughage mix in fed cattle rations. IFOAM (1989, pp. 26, 38) states that "for ruminants, forage should constitute no less than 60% of the total daily dry matter intake. . . . High energy, low fiber rations and those with more than 40% dry matter concentrate feeds" are prohibited. This requirement is reflected in the negative score and the single threshold for percentage of grain to total dry matter intake for the three different stages of feeding shown for the POI in Table 1. Animal nutrition research underlies assigning less negative scores during later feeding stages.

We based the POI scores for feeding systems shown in Table 1 on the statements of five organic certification sources that take positions regarding confinement feeding versus grazing in fed cattle production. CCOF (1993, p. 20) states the "CCOF livestock producers are encouraged to provide all animals with access to pasture or outside runs." IFOAM (1989, p. 25) states that "all stock should have access to pasture during the grazing season unless specifically exempted by the Certification Committee." NOSB (1993, p. 14) states that "year-round confinement of livestock to an outdoor drylot without seasonal access to pasture or grazing land shall be prohibited." NPSAS (1992, p. 1) states that "stock should have access to outdoor range." Organic Food Producers Association of North America (OFPANA and OFAC, 1992, p. 3) states that organic livestock shall have "access to pasture and sunshine when seasonally and ecologically sound."

The rationale for the scores for the two feeding practices in the PSI is that beef cattle, as ruminants, are uniquely designed to make effective use of roughages. In many areas, beef cattle are more effective than other species in using rangeland and forages in crop rotations. From this standpoint, feeding high proportions of concentrates to beef cattle can conflict with efficient natural resource use. Feeding "excessively" high proportions of concentrates to finishing cattle can sometimes also harm their health and welfare or result in meat with a fat level that may be harmful to human health. On the other hand, the positive potential of some genetically superior, fast-growth feeder calves can be realized more fully, without a penalty of excessive fat, if the calves are placed on heavy concentrate rations from weaning until a little more than a year of age, when they are ready for slaughter.

2. *Scoring use of growth promotants and antibiotics.* POI scores for growth promotants shown in Table 2 are based on a strong consensus among the eight organic certification sources that organic producers should not use growth promotants and hormones. Because single-component animal production research shows that cattle receiving growth promotants have improved daily weight gain, feed conversion efficiency and lean meat development, PSI scores for growth promotants differ substantially from those for the POI. However, we assigned only moderate positive scores for growth promotants in the PSI because of some question about whether continued reliance on them is consistent with long-term sustainable cattle production.

We based the POI scores for antibiotics shown in Table 2 on the following positions taken by the eight organic certification sources.

- CCOF (1993, pp. 20–21, 29) states that "subtherapeutic feeding" and "routine" use of antibiotics are prohibited and that "livestock producers must never deny treatment to an ill animal so that its products may be labeled 'organic'."
- IFOAM (1989, pp. 28–29) says that "the aim should be to reduce the use of antibiotics to a minimum or, if possible, eliminate their use altogether. . . . For conditions requiring treatment and where effective alternative treatments are not available, conventional drugs should be used, in particular to save life, to prevent unnecessary suffering, or to provide the only way to restore the animal to full health. Treatment should never be withheld where an animal is suffering. Withdrawal periods must be observed. Treatment of healthy animals and the routine use of prophylactic drugs is prohibited, except in cases of a known farm disease problem."
- NOSB (1992) reports controversy around whether animals treated with antibiotics "should be removed from the certified herd or if some extended withdrawal time is acceptable." Of all respondents, 32% supported prohibition of all antibiotic use; 65% of them supported

Table 1. Scores assigned to selected feeding practices, POI and PSI.

Feeding Practice	Score	
	POI	PSI
Grain as fraction of total dry matter intake[1]		
Backgrounded steers (500–750 lb): >40%	–8	–8
Early finishing steers (750–950 lb):		
>40%	–6	n/a
>70%	–6	–8
Late finishing steers (950+ lb)		
>40%	–4	n/a
>80%	–4	–8
Feeding system		
Entirely confinement feeding	–4	–2
Grazing during part of backgrounding, confinement feeding thereafter	–2	0
Grazing during entire backgrounding, confinement feeding thereafter	+2	0
Grazing, followed by confinement feeding for <100 days	+4	0

[1] A score of 0 was assigned when the stipulated feeding condition was not met.

Table 2. Scores assigned to use of growth promotants and antibiotics in fed cattle production, POI and PSI.

	Score	
	POI	PSI
Use of growth promotants		
No cattle	0	–1
Some cattle	–8	+1
All cattle	–16	+2
Use of antibiotics		
To treat specific sicknesses/injuries	+8	+4
Subtherapeutic	–8	–2
For newly purchased cattle upon arrival at feedlot	–4	+2
Never	–4	–4

allowing restricted use of antibiotics with extended withdrawal periods.

- NOSB (1993, pp. 8, 13) states that "antibiotics—systemic and topical" are excluded from the National List of exempted synthetics. "The action of a producer to withhold treatment to maintain the organic status of an individual livestock animal which results in the otherwise avoidable suffering or death of the animal shall be grounds for decertification." OFPANA (1992, pp. 1, 304) takes essentially the same position.
- OFPA (pp. 21–26) states that producers shall not "use subtherapeutic doses of antibiotics." The positions of NPSAS (1992, p. 1) and OCIA (1993, p. 5) are essentially the same. Based on these statements, we assigned the POI scores for antibiotics shown in Table 2.

The rationale for the PSI scoring of antibiotic use shown in Table 2 is as follows. Some cattle feeders conceivably could follow such finely tuned management practices that no animals would become sick or injured, so that they would be well advised never to use antibiotics. However, some types of sickness and injury are likely to occur in most feedlots. Therefore, we assigned positive scores to producers who use antibiotics to treat specific sicknesses and injuries, and negative scores to those who never use antibiotics. Animal productivity and welfare are almost certain to suffer if producers follow a blanket policy of never using antibiotics.

Because cattle can develop resistance from continuous use of antibiotics, and because its benefits are likely to be less than its costs, we assigned a negative score to producers who regularly include subtherapeutic doses of antibiotics in feed. On the other hand, use of antibiotics with newly purchased feeder cattle was assigned a slightly positive score. Using antibiotics prophylactically with calves just placed in the feedlot, particularly calves from outside, is likely to result in healthier calves that will earn higher profits.

3. *Comprehensive overview of weights assigned to management practices.* Table 3 shows the relative weights assigned to all management practices covered in the POI and PSI. These weights are expressed as percentages of the respective index's absolute range: 219 for the POI and 214.5 for the PSI (Taylor and Feuz, 1993, pp. 39, 48). For example, a producer feeding more than 40% grain as a fraction of total dry matter intake during each of the three feeding stages would earn a maximum POI score of –18, or 8.2% of 219. Similarly, the maximum possible PSI score for that practice would be –24, or 11.2% of 214.5.

In identifying major differences between the POI and PSI, we noted management practices unique to each index. Practices unique to the POI are: feeding organically produced feedstuffs, prohibiting "alternative" feeds (e.g., manure, urea, bone meal, sawdust, plastic roughage), and maintaining health records on individual animals (to provide an "audit trail"). Organic certification authorities believe that these practices and the absence of growth promotants and antibiotics (except for extreme sickness or injury) contribute to animal health and welfare and reduce harmful chemical residues in meat products.

Practices unique to the PSI are a variety of farm and ranch, feeding, and cattle management practices and the home-raising of feedstuffs. There is strong evidence that attention to these practices will improve the physical and economic performance of cattle and make more efficient and less risky long-term use of producers' financial resources.

Home-raising of feedstuffs is included in the PSI because it reduces fossil fuel consumption and cash expenditures for transporting feedstuffs and reduces the producer's risk of having to purchase high-priced feedstuffs in short supply. Raising feeds at home also can help insure that the feeds will be of uniformly high quality. On the other hand, some otherwise sustainable producers might find it is cheaper to buy certain feedstuffs than to produce them themselves.

Finally, only three of the eight organic certification sources take a position on manure management. CCOF (1993, pp. 25, 32) and OCIA (1993, p. 2) both recommend composting manure and applying manure to land in particular ways. Only OFPA (pp. 21–29) explicitly emphasizes limiting land manure applications to levels that will not contaminate soil and water. A major challenge to sustainable beef cattle production is insuring that soil and water are not damaged by point and non-point sources of pollution associated with animal wastes (National Research Council, 1993). Although we did not have sufficient information to give much attention to this issue in the PSI, we advocate greater attention to it in future efforts to improve the PSI and in establishing standards for organic beef production.

Empirical Estimation: South Dakota Fed Cattle POI and PSI

Feedlots studied

We obtained data for the empirical estimation of the fed cattle POI and PSI from the responses of 102 South Dakota cattle feeders (most of whom also manage farmland) to a mail survey in winter 1991–92. Questionnaires were mailed to all cattle feeders officially reported to have a feedlot capacity of 500 head or more, and to a random sample of approximately 12% of operators of feedlots with less than 500 head. Of the 500 questionnaires sent out, 241 were returned, for a response rate of 42%. However, of the 241, only 102 fed slaughter

Table 3. Relative weights assigned to management practices in POI and PSI.

Management practice	Weight in total index (%)	
	POI	PSI
Feeding		
Feeding "organically" produced feedstuffs	15.1	0
"Alternative" feeds prohibited (e.g., plastic pellets for roughage, recycled manure, urea, anhydrous ammonia, sawdust and other non-food ingredients)	12.3	0
Percentage grain to total dry matter intake in cattle rations	8.2	11.2
Feeding system: Confinement during entire feeding period	3.7	0.9
Percentages of various feedstuffs that are home-raised	0	5.6
Selected feed management practices followed (e.g., feedstuff nutrient composition tested at least once a year, feed records kept for separate pens of cattle, feed scales used)	0	5.6
Subtotal	39.3	23.3
Health management		
Nature of use of production tools such as antibiotics, growth promotants, ionophores, coccidiosis control, parasiticides, insecticides/fumigants, vaccinations	25.5[1]	12.8
Selected features of cattle finishing operation (e.g., mounds, bedding, shelterbelt windbreaks, feedlots partially paved with concrete)	7.8	8.4
Facilities for segregating sick or injured animals	1.8	1.9
Records maintained on amounts and sources of medications administered to individual animals	1.8	0
Subtotal	36.9	23.1
Drinking water access/quality		
Drinking water quantity problems experienced	2.7	10.0
Drinking water quality problems experienced	3.7	6.4
If problems, actions taken to overcome the problems	3.7	6.4
Subtotal	10.1	22.8
Manure management		
Manure composted	5.5	3.7
Intensity of manure application	8.2	8.4
Subtotal	13.7	12.1
Overall farm/ranch and cattle management		
Farm/ranch debt-to-asset ratio	0	4.7
Percentage of family labor used in feeding cattle	0	4.7
Percentage of feedlot utilization	0	3.7
Percentage of total cattle placed on feed that is home-raised	0	2.8
Cattle weights monitored	0	1.9
Have grain storage facilities to take advantage of price drops in purchased feed grains	0	0.9
Subtotal	0	18.7
TOTAL	100.0	100.0

[1] In the POI, only the following production techniques were considered: antibiotics, growth promotants, parasiticides, and vaccinations.

cattle; the others either had stopped or fed cattle only during an early phase of finishing. (The managerial practices followed by survey respondents are reported in Taylor and Feuz, 1994.) The design capacity for the 102 feedlots ranges from 11 to 6,665 head. It averages 935, which is more than 10 times the state-wide average of about 90 head (computed from an average of 180 fed cattle marketed per feedlot, assuming two batches of cattle being fed in each feedlot per year, [U.S. Dept. of Commerce, 1994, p. 29]).

A majority (71%) of the respondents have livestock enterprises other than cattle feeding. Beef enterprises include cow herds (64%), feeder calves (15%), and stocker cattle (9%). Other livestock enterprises include slaughter hogs (18%), farrowing (14%), dairy herds (11%), and sheep and poultry (less than 5% each).

The 102 feedlot managers manage an average of 555 ha of cropland, which is 2.1 times the average of 265 ha for farms/ranches throughout the state (U.S. Dept. of Commerce, 1994, p. 8). About 42% obtain more than 75% of their annual gross farm income from the sale of livestock; fewer than 5% of them obtain less than 25% of gross income from livestock.

Their average age is 48 years, compared with 51 years for farmers/ranchers in the state (U.S. Dept. of Commerce, 1994, p. 8). About 12% of the feedlot managers reported they own their farms/ranches debt free, while 30% reported a debt-to-asset ratio of 0.40 or greater.

Empirical estimation procedures

We estimated POI and PSI values using procedures similar to those used for the FSI for cabbage producers in Malaysia (Taylor et al., 1993), including how values were imputed for missing data. Final POI and PSI values were adjusted by a linear transformation, with the highest and lowest possible raw scores of each index becoming 0 and 100, respectively.

However, we did not follow the steps involving item selection, bivariate selection, and index validation through item analysis that resulted in dropping some practices in the Malaysian study. We based this decision on a judgment that the practices included in the fed cattle indexes should reflect an *a priori* assessment of the importance of

particular practices, rather than on whether the practices included in the final indexes met certain statistical criteria. For external validation, the research team communicated individually with 17 farm producers, organic certifying organization officials, and natural and social scientists at two different stages in development of the indexes.

Estimated POI

Individual POI values range from 31 to 82, with an average of 49 (Table 4). Ten percent of the values are less than 40, about 70% are between 40 and 55, and 20% are greater than 55. (Data for this and the next two sub-sections are taken from Guan, 1994.)

To assess the stability of the baseline POI results reported in Table 4, we did a sensitivity analysis in which the weight for each of the four type-of-practice groups (see type-of-practice subtotals in Table 3) was successively increased by 30%, while the weights for the three other type-of-practice groups were reduced so that the range in POI score was the same as in the baseline POI. We computed the Spearman's rank correlation coefficient to determine how much each adjustment changed the POI compared with the baseline POI ranking. The four estimated rank correlation coefficients ranged from 0.944 to 0.999.

To determine the relative strength of the 102 feedlot operators in feeding, health management, manure management and drinking water, each producer's score for each type-of-practice group was computed as a fraction of the highest possible score for that group. The means of these percentages are shown at the top of Table 5. The feedlot operators are stronger in their drinking water (65%) and health management (61%) practices than in their manure management (39%) and feeding (37%) practices.

To determine whether producers with higher POI values also tend to be strong in individual types of practices, we divided the feedlots into five consecutive intervals of POI values. The distribution for each type-of-practice group by POI value is shown in the lower part of Table 5. POI values showed a consistent relationship with the quality of feeding, health management, and manure management practices, but not with drinking water. Feedlots with high and low values differed more in their manure management and feeding practices than in health management.

Estimated PSI

PSI values range from 49 to 81, with an average of 66 (Table 4). Twenty-two percent of the values are less than 60, about 66% are between 60 and 75, and 12% are greater than 75. In a sensitivity analysis similar to the one described above, the five rank correlation coefficients between the baseline PSI and each adjusted version of it ranged from 0.959 to 0.996, again reflecting stability in the baseline PSI.

From the standpoint of sustainability, feedlot operators studied are strongest in health management (80%), followed by drinking water (72%), feeding (63%), overall farm/ranch management (53%), and manure management (46%) (Table 6). Each type-of-management practice is positively associated with PSI, except drinking water. Feedlots with high and low PSI values differ the most in manure management, followed by feeding, overall farm and ranch management, and health management.

Table 4. POI and PSI values for 102 cattle feeders.

POI		PSI	
Range	31.2–81.7	Range	49.2–80.6
Mean	49.4	Mean	65.8
Frequency distrib. (%)		Frequency distrib. (%)	
0.0–40.0	9.8	0.0–55.0	8.8
40.1–45.0	24.5	55.1–60.0	12.7
45.1–50.0	22.6	60.1–65.0	21.6
50.1–55.0	23.5	65.1–70.0	28.4
55.1–60.0	9.8	70.1–75.0	16.7
>60.0	9.8	>75.0	11.8

Comparison of estimated POI with estimated PSI

In the previous section, we discussed differences between the managerial practices included in the POI and PSI. The sample rank correlation coefficient between the two indexes is 0.46. Although this is significantly different from zero ($p<0.01$), only 21% of the variation in the POI is associated with variation in the PSI. Thus, the organic certification standards for organic beef for the eight sources used here are only loosely related to sustainable beef production practices.

Adoption of Organic and Sustainable Practices

To determine factors associated with adoption of organic and sustainable practices, we regressed POI and PSI on 9 independent variables that were not used in either index (SAS Institute, Inc., 1988). The following five categories of independent variables were used: farm size, farm type, farm location, family characteristics, and self-perception (organic versus mainstream/conventional). We hypothesized that POI and PSI would have the following relationships to these independent variables:

1. Farm size variables
   Feedlot design capacity (1,000 head): Inverse relationship, since the managerial and labor requirements for organic and sustainable production may be greater than for mainstream production.
   Cropland (1,000 acres): Inverse relationship, for the same reason.
2. Farm type variables
   Livestock other than fed cattle (yes = 1; no = 0): Direct relationship, since enterprise diversification can be a way to achieve organic and sustainable production.
   Percentage of gross farm income from livestock: No hypothesized relationship.
3. Farm location variables. (The two regions below are compared with the Northeast Region, which is loaded into the intercept.)
   West Region (feedlot located west of the Missouri River; yes = 1, no = 0): Direct relationship, since research on crop production in South Dakota shows that farmers in the west generally follow more sustainable production practices than those in the east.
   Southeast Region (feedlot located in the southeastern part of the state; yes = 1, no = 0): No hypothesized relationship.

Table 5. Mean scores for various types of production practices, by POI range.

	Mean type-of-practice score			
	Feeding	Health management	Manure management	Drinking water access/quality
Overall mean	37.4	61.4	38.9	64.9
Range in POI				
0.0–39.9	28.3	45.5	11.3	63.6
40.0–49.9	31.0	60.0	31.4	64.4
50.0–59.9	40.5	64.9	52.5	65.8
60.0–69.9	64.2	69.4	46.7	66.2
≥70	72.8	79.7	91.7	63.6

Table 6. Mean scores for various types of production practices, by PSI range.

	Mean type-of-practice score				
	Feeding	Health management	Manure management	Drinking water access/quality	Overall farm/ranch management
Overall mean	63.1	80.1	45.5	71.5	53.4
Range in PSI					
0.0–54.9	32.7	75.9	15.9	70.9	43.3
55.0–59.9	48.7	78.4	15.4	69.7	46.3
60.0–64.9	57.8	78.6	35.2	69.3	45.8
65.0–69.9	66.8	78.0	52.6	72.3	57.1
70.0–74.9	75.3	86.1	60.2	71.2	59.7
≥75.0	84.1	84.3	81.7	76.6	64.2

4. Family characteristic variables
   Farmer employed off-farm (yes = 1, no = 0): Uncertain relationship: off-farm income could help make up for the possibly lower farm income for organic and sustainable producers compared with mainstream producers, leading to a direct relationship; however, the relationship could be inverse, since managerial and labor requirements for organic and sustainable production may be greater than for mainstream production.
   Farmer's spouse employed off-farm (yes = 1, no = 0): Uncertain, for the same reason.
5. Farmer's perception
   Farmer self-perceived as "organic" (yes = 1, no = 0): Direct relationship, since the perceived nature of farmers' practices is expected to be consistent with their actual practices, as measured by POI and PSI.

Results of the multiple regressions are displayed in Table 7. Both regressions are statistically significant ($p<0.01$). The percentages of variation in POI and PSI explained by the independent variables in each regression are modest (25–26%).

The only variable that is statistically significant in both regressions is "farmer's spouse employed off-farm." In the POI regression, "farmer employed off-farm" also is statistically significant. Thus, there is some evidence that farmers with higher POI and PSI tend to seek off-farm employment to augment farm income, rather than to spend more time on-farm meeting the possibly greater managerial and labor requirements of organic and sustainable production. In the POI regression, the coefficients on two other variables differ significantly from zero: "livestock other than fed cattle" with an expected positive sign, and "Southeast Region" with a negative sign.

In the PSI regression, both farm size variables are statistically significant. "Cropland" is directly related to PSI, as hypothesized. "Feedlot design capacity," however, unexpectedly has an inverse relationship to PSI. The relationship of "West Region" to PSI is statistically significant and direct, as hypothesized. "Farmer self-perceived as 'organic'" also is statistically significant, but its sign is unexpectedly negative. One possible explanation is the loose connection noted above between the two indexes.

Conclusions

This exploratory study contrasts "organic" and "sustainable" agricultural production. An important motivation underlying the study was our concern that current certification standards for organically produced commodities fail to give adequate attention to certain critical dimensions of sustainability.

We explored the possible differences between organic and sustainable systems by developing two indexes for production of fed cattle. The POI reflects current production standards for organically certified beef, in which paramount concerns are animal health and welfare and consumer health. The PSI was designed also to cover cattle producers' long-term natural resource conservation and economic staying-power.

We recognize that these indexes require further refining, but we believe that the method has promise for providing insights useful to several groups: to policymakers in refining certification standards for organic beef production and determining how to encourage adoption of organic and sustainable production practices; to extension specialists in identifying strengths and weaknesses in producers' current feedlot management practices; and to individual producers in identifying strengths and weaknesses in their own practices.

Acknowledgment. We greatly appreciate the insightful comments and suggestions provided on an earlier draft of this paper by Donald M. Kinsman, Dept. of Animal Science, University of Connecticut and Kathleen Merrigan, Henry A. Wallace Institute for Alternative Agriculture.

References

1. California Certified Organic Farmers. 1993. California Certified Organic Farmer Handbook. Santa Cruz, California.
2. Ewbank, R. 1988. Animal welfare. In Management of Welfare of Farm Animals. The UFAW Handbook. 3rd ed. Bailliere Tindall, London. pp. 1–12.
3. Gershuny, G. 1993. Editorial: Organic and sustainable: Debate or dialogue? Organic Farmer: Digest of Sustainable Agric. 4(1):7.
4. Guan, M. 1994. Sustainable production practices adopted by beef cattle producers in South Dakota. M.S. thesis. Economics

Table 7. Socioeconomic factors associated with organic and sustainable cattle feeding.

	Regression	
	POI	PSI
Regression parameters		
F-ratio of regression	3.36***	3.20***
Adjusted R^2	0.258	0.245
Number of feedlots	62	62
Production coefficients		
Intercept	0.458***	0.594***
Cropland (1,000 acres)	–0.007	0.010*
Feedlot capacity (1,000 head)	–0.008	–0.016**
West Region	0.022	0.069*
Southeast Region	0.028*	0.002
Livestock other than fed cattle	0.029*	0.025
Farmer employed off-farm	0.041**	0.024
Spouse employed off-farm	0.037**	0.049***
% of gross farm income from livestock	0.017	0.028
Farmer self-perceived as "organic"	0.045	–0.160***

***, **, and * denote statistical significance levels of p<0.01, p<0.05, p<0.10, respectively.

Dept., South Dakota State Univ., Brookings.

5. International Federation of Organic Agriculture Movements. 1989. General standards for livestock husbandry. Soil Assoc., Bristol, England.
6. International Federation of Organic Agriculture Movements. 1991. Minutes: Animal standards sub-committee meeting. Soil Assoc., Bristol, England.
7. Manley, R. 1994. Comment: A mess in the market. New Farmer & Grower. Issue 44(Autumn):12–13.
8. New Farmer and Grower. 1994. Changes to organic regulations proposed. Issue 42 (Spring):7.
9. National Organic Standards Board. 1992. Report of the National Organic Standards Board on results of a mail survey of 252 organic producers. Washington, D.C.
10. National Organic Standards Board. 1993. National standards for organic production. Washington, D.C.
11. National Research Council. 1993. Soil and Water Quality: An Agenda for Agriculture. Board on Agriculture. National Academy Press, Washington, D.C.
12. Northern Plains Sustainable Agriculture Soc. 1992. A guiding philosophy for sustainable agriculture: Organic production standards and principles. Maida, North Dakota.
13. Organic Crop Improvement Association. 1993. OCIA certification standards. Bellefontaine, Ohio.
14. Organic Farmer: Digest of Sustainable Agric. 1993. Organic and sustainable: Debate or dialogue? Vol. 4(1):14–21.
15. Organic Foods Production Act of 1990. In Food, Agriculture, Conservation, and Trade Act of 1990, Public Law 101–624, 101st Congress, Nov. 28. pp. 3359–4078.
16. Organic Food Producers Association of North Amer. and Organic Farmers Assoc. Council. 1992. Draft livestock standards.
17. SAS Institute, Inc. 1988. SAS/STAT User's Guide, Release 6.03 Edition. Cary, North Carolina.
18. Skal. 1991. Eko standards: Standards for sustainable organic agriculture and for processing organic agricultural products. Skal (Inspection organization for organic production methods), Zwolle, Netherlands.
19. Taylor, D.C., and D.M. Feuz. 1993. Beef cattle producer sustainability and organic indices. Economics Staff Paper 93–6. Economics Dept., South Dakota State Univ., Brookings.
20. Taylor, D.C., and D.M. Feuz. 1994. Cattle feedlot management in South Dakota. Economics Research Rep. 94–1. Economics Dept., South Dakota State Univ., Brookings.
21. Taylor, D.C., Z.A. Mohammed, N.N. Shamsudin, M.G. Mohayidin, and E.F.C. Chiew. 1993. Creating a farmer sustainability index: A Malaysian case study. Amer. J. Alternative Agric. 8:175–184.
22. U.S. Dept. of Agric. 1995. National Organic Standards Board documents. Agric. Marketing Service, Transportation and Marketing Div., Washington, D.C.
23. U.S. Dept. of Commerce. 1994. 1992 Census of Agriculture. Vol 1, Geographic Area Series. Part 41: South Dakota and County Data. Bureau of the Census. Washington, D.C.
24. Wilder, J.R. 1991. Sustainable agriculture and the U.S. cattle industry: An examination of laws, production practices, and research studies. Master of Laws thesis. Univ. of Arkansas, Fayetteville.

Farm Bill Includes Advisory Panels, Competitive Grants

The 1996 farm bill creates two advisory panels and provides funding in the Fund For Rural America for a competitive grants program in research, education, and extension. The farm bill consolidates USDA's Agricultural Science and Technology Review Board, the Joint Council on Food and Agricultural Sciences, and the National Agricultural Research and Extension Users Advisory Board into a single National Agricultural Research, Extension, Education, and Economics Advisory Board with 30 members. It also establishes the USDA Strategic Planning Task Force, a 15-member panel to review the capacities of 107 federal research locations and the facilities at 76 land grant universities.

For research activities, the Fund For Rural America establishes a competitive grants program for colleges and universities and their foundations, federal research agencies, national laboratories, and private research organizations with established and demonstrated capacities to perform research on technology transfer. The competitive grant funds will be available between January 1, 1997, and October 1, 1999. For more information contact Steve Teasley at (202) 720-8319, or Maria Bynum at (202) 720-5192.

Effects of free-range chickens and geese on insect pests and weeds in an agroecosystem

M. Sean Clark and Stuart H. Gage

Abstract. *We evaluated the effects of free-range chickens and geese on insect pests and weeds in an experimental, nonchemical agroecosystem consisting of an apple orchard with intercropped potatoes. The objective was to assess the potential of these domestic bird species as biological control agents. Four insect pests were studied: plum curculio, apple maggot, Japanese beetle, and Colorado potato beetle. Chickens fed on several potential crop pests, including Japanese beetle. Although Japanese beetles were less abundant on apple trees when chickens were present, the proportion of damaged fruit was not reduced. Furthermore, chickens did not affect weed abundance or crop productivity. In contrast, geese were effective weeders. Their activities reduced weed abundance and increased potato plant growth and yields compared with a minimally weeded control. In addition, the activities of geese indirectly reduced apple fruit damage by plum curculio and increased the proportion of pest-free fruit, possibly because removal of vegetation by the geese reduced humidity at the soil surface and therefore reduced the activity of plum curculio.*

Key words: chickens, geese, biological control, insect management, weed management

Introduction

The integration of animals into cropping systems potentially can reduce the need for external farm inputs. Benefits can include nutrient cycling and conservation, utilization of crop residues, economic stability through market flexibility, and vegetation and weed management (King, 1990; Parker, 1990; Gillen and Scifres, 1991; Loomis and Connor, 1992; Bender, 1994). Most efforts at animal integration in the United States have focused on large livestock, specifically cattle. However, smaller livestock species and breeds, sometimes termed microlivestock, can play various roles on small farms and market gardens, including insect pest control, weed management, sanitation, and product diversification.

The use of livestock as biological control agents is unusual compared with arthropods and microbes. The reasons include the limited choice of species, the lack of research, and the large investment of labor and land required. Furthermore, the use of livestock requires more managerial experience and skill. Nevertheless, small and large livestock have been successfully employed as biological control agents, mainly for weeds. Examples include using geese to control weeds in strawberry (Cramer, 1992; Bachman, 1993; Ware, 1995) and cotton (Mayton et al., 1945; Johnson, 1960). Recent experiments by Wurtz (1995) showed the potential for using geese in an integrated weed management strategy during the establishment of tree seedlings. Sheep and goats also are useful for managing weeds in orchards and woodlots (Shirley, 1992) and for removing brush (Olkowski et al., 1991).

Compared with weed management, the use of livestock for insect pest management is poorly documented. Anecdotal information suggests that poultry can reduce the abundance of Colorado potato beetle on potato (Casagrande, 1987), flies in cattle pasture (Salatin, 1991), and orchard pests (Quaintance and Jenne, 1912; Hoare, 1928; VABF, 1993). However, there is no experimental evidence to support these claims. Muscovy ducks have been shown experimentally to reduce house fly populations substantially in dairy and swine operations, an option that appears economically feasible (Glofcheskie and Surgeoner, 1990; 1993).

Clark et al. (1995) discussed the behaviors and activities of free-range domestic chickens and geese in a nonchemical food production system consisting of apple and potato. Chickens were omnivorous, feeding on weed seedlings, seeds, insects (including several pest species), and soil invertebrates. Geese, in contrast, fed almost solely on grasses and broadleaf weeds. Both chickens and geese were compatible with the experimental agroecosystem and showed promise for managing insect pests and weeds, respectively, in small-scale operations.

This paper reports the results of experiments intended to measure the effectiveness of chickens and geese as biological pest management agents. It had two objectives: to measure the effects of free-range chickens and geese on the abundance of several important insect pests and on weeds in a nonchemical agricultural production system; and to assess the potential of these domestic birds as crop protection agents, based on their effects on crop productivity and pest damage.

Materials and Methods

Study site

All research was conducted during 1994 and 1995 in a 0.5 ha apple orchard block at the Kellogg Biological Station, Hickory Corners, Michigan. The block, planted in 1983 at a density of 430 trees/ha, consisted of three disease-resistant cultivars, 'Redfree', 'Priscilla', and 'Liberty', on M.26 rootstocks. It has been managed without the use of pesticides since establishment. The trees

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were pruned annually, with all cuttings burned or removed from the orchard. The fruit have not been thinned, therefore harvests have alternated biennially between high and low yields. Apple drops have been removed from the orchard in years of heavy yield. In 1994, codling moth was managed with pheromone disruption. The ground cover throughout the orchard consisted primarily of orchardgrass *(Dactylis glomerata)* and Kentucky bluegrass *(Poa pratensis),* but more than twenty other species also were identified. The alleys of the block were intercropped with potatoes in 1993. Other vegetable crops, including beans and tomatoes, were intercropped in smaller areas of the block in previous years.

Effects on insect pests and weeds

In 1994, we evaluated the effects of domestic chickens and geese on insect pests and weeds in the orchard block. The alleys were planted to potatoes ('Red Pontiac') at 30 cm plant spacings and 75 cm row spacings on 6 May 1994. This arrangement allowed for three rows of potatoes in each alley (Fig. 1). Nine plots were established, each 28 m × 12 m. Each plot consisted of five rows of four trees. Twelve of the trees were 'Redfree'; the remaining 8 trees were 'Priscilla' or a combination of 'Priscilla' and 'Liberty'. The plots were allocated randomly to one of three treatments: 1) with 20 Barred Plymouth Rock chickens per plot (chicken treatment); 2) with 7 African geese per plot (goose treatment); and 3) no birds (control). Thus, there were three plots per treatment. On 14 May, the designated number of 6-week-old birds were introduced into the plots. The birds were allowed to free-range from 8 A.M. until 9 P.M. each day, and at night were put into coops (1.2 m × 1.2 m) located in the center of each plot. The flock in each plot was provided with 0.1 to 0.2 kg of grain-based commercial feed each morning and evening.

On the night of 18 May, 30 chickens and 11 geese were stolen from the experiment. The stolen geese were replaced the following day with geese of the same age. Replacement chickens of the same variety and age were not immediately available. Therefore, chicken density was maintained at 10 birds per plot until 14 June, when nine 3-week-old White Plymouth Rock chickens were added to each plot. This set the density at 19 chickens per plot. Over the course of the experiment, more chickens were lost to predators. These losses were monitored but not replaced. Final chicken density on 5 August was 12 per plot.

We measured the population dynamics of four insect pests, plum curculio *(Conotrachelus nenuphar),* apple maggot *(Rhagoletis pomonella),* Japanese beetle *(Popillia japonica),* and Colorado potato beetle *(Leptinotarsa decemlineata).* The first three damage apple fruit directly, while the last feeds on potato foliage. Japanese beetle also feeds on apple and potato foliage. We selected these insects because they are serious economic pests of these crops and because they spend at least one stage of their life cycle on the soil surface, where they can be eaten by chickens.

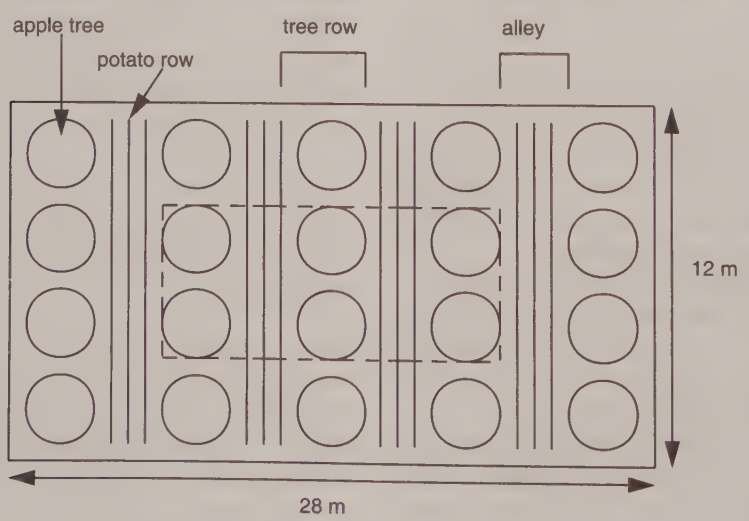

Figure 1. Layout of a single plot. Four of the six apple trees within the dotted box in the center of each plot were designated as sampling trees for all insect pest monitoring.

Four of the six trees in the center of each plot were designated for monitoring the three apple pests (Fig. 1). When possible, two of the trees were 'Redfree' and two were 'Priscilla'. In plots where a 'Priscilla' tree was missing or dying, an additional 'Redfree' was monitored. We monitored plum curculio indirectly by examining all fruit for oviposition and feeding damage on four branches per tree, each week during June. Apple maggot was monitored by counting the number of adults on unbaited, red spheres covered with adhesive. One sphere was hung 1.5 m high in each sampling tree on 26 June and sampled every 10 days until 5 August. We monitored Japanese beetle abundance directly by counting all beetles on each sampling tree every 5 to 10 days from 30 June until 5 August.

Colorado potato beetle larvae and adults were counted at eight designated areas in each plot. Each sub-sampling area consisted of three 1 m lengths of potato row, resulting in a total of 24 m of row per plot. Counts were conducted every 5 to 10 days from 14 June until 29 July.

We monitored potato growth and weed abundance by measuring the ground cover of potato and other plants at four locations in each plot. Ground cover was measured using a 1 m^2 quadrat with wires forming an 81-point grid centered over the middle potato row in each alley. The presence or absence of potato and other foliage was determined at each grid point. The data from the four locations of each plot were pooled and used to calculate percentage ground cover of potato plants and weeds.

We measured yields of apple fruit and potato tubers at harvest. Apple fruit yield and damage assessments were restricted to 'Redfree' because of the uneven distribution of the other two cultivars across the experimental site. Because of the human health risks associated with domestic animal manures, only apples on the trees, but not drops, were included in yield determinations. On 18 August, the fruit from all 'Redfree' trees in each plot was weighed and five apples from each tree were selected randomly for assessing insect damage. These were examined for damage by plum curculio, apple maggot, and Japanese beetle. We also recorded damage by codling moth and tarnished plant bug. Fruit with no insect

damage or blemishes of any kind were considered pest-free. Potato yields were estimated on 3 August by digging and weighing the tubers in 6 m of row in two of the four alleys of each plot. Insect pest and weed abundances in the treatments were compared graphically using time-series data. Fruit yield and damage and potato yield were compared graphically and statistically with one-way analysis of variance (ANOVA) followed by Tukey's honestly signficant difference (HSD) test, using SYSTAT (SYSTAT, Inc., Evanston, Illinois).

Performance of an integrated bird system

In 1995, we evaluated the performance of an integrated bird system that included free-range chickens and geese. The integration of the two bird species into a single treatment was intended to combine the weeding effects of the geese with the potential insect pest reductions from the chickens. This experiment included two treatments with three replications: free- ranging chickens and geese in the system as needed for vegetation and insect pest management (bird treatment); and light hand weeding with no birds (control). The bird treatment and control were assigned to the plots that in 1994 had been used for the goose treatment and control, respectively. Potatoes were planted on 3 May 1995 using the same protocol as described for the experiment in 1994.

Seven geese, 5 weeks old, were introduced to each plot of the bird treatment on 8 May. Within three weeks most of the preferred plant species (common dandelion, common plantain, and grass seedlings) had been eliminated by the geese. Therefore, on 28 May four geese were removed from each plot, setting the density at three per plot. These geese were kept in the plots until 13 June. Three geese were put back into the bird treatment plots for five days in early July to eliminate emerging grass seedlings.

Following the removal of the geese on 13 June, we introduced a flock of 20, ten-week-old, Barred Plymouth Rock chickens into each plot of the bird treatment. (Before introduction, the chicken flocks had been maintained in the areas next to the experimental plots in the orchard block.) The chicken flocks were kept in the plots until 1 August. However, during this time an average of six chickens per plot (30% of each flock) were lost to predators, primarily hawks and owls. Chicken flocks were maintained at equal densities by moving birds from undisturbed plots into plots where predation had occurred. In addition, four chickens were removed from each plot on 12 July for the chicken diet analysis (described below). Thus, when the bird treatment ended on 1 August, each plot had 10 chickens.

The bird treatment plots were hand weeded once (30 June) to remove unpalatable weeds, primarily daisy fleabane *(Erigeron annuus)* and curly dock *(Rumex crispus)*. Weed management in the control plots consisted of a single mowing in the tree rows and two cultivations in the potato alleys. Vegetation in the tree rows was cut to 15 cm using a gasoline-powered trimmer on 13 June. Potatoes in the control plots were cultivated first on 15 June using a rototiller between the rows and a hand hoe within the rows. The second cultivation was completed on 5 July with a hand hoe because the soil was wet.

We measured all variables related to insect and weed abundance and crop growth, yield, and damage according to the protocols described for 1994, with these exceptions: plum curculio abundance was not monitored in 1995; ground cover of individual weed species was determined on one sampling date, 30 May; and the weight of apple drops was determined for the four sampling trees of each plot and compared between the treatments as the percentage of total yield. We measured potato yields on 2 August and apple yields on 22 August. Insect pest abundance, weed abundance, fruit yield and damage, and potato yield were analyzed and compared as described for the 1994 experiment.

Free-range chicken diet analysis

Clark et al. (1995) reported that it was more difficult to observe the feeding habits of free-range chickens than geese because their diet consisted mostly of small insects and other invertebrates on the soil surface, rather than plants. We needed information on the diet of free-range chickens to corroborate feeding observations (Clark et al., 1995), insect pest abundance patterns, and fruit damage levels. Thus, to identify items constituting the chicken diet, we dissected digestive crops of chickens killed by predators and sampled for experimental purpose. Many chickens killed by raptors were decapitated but had little damage to the rest of the body. Between 6–19 June, ten chicken carcasses were found in good condition and promptly frozen for dissection. In addition, on 19 July, four chickens were removed from each bird plot and slaughtered. All the digestive crops were dissected and the contents identified, usually to the taxonomic family.

Results

Effects on insect pests and weeds

In 1994, apple yields were high for this orchard, but similar among the treatments. Mean fruit weight per tree for 'Redfree' trees in the control, chicken, and goose treatments were 31, 36, and 34 kg, respectively.

Graphical comparisons showed that plum curculio (Fig. 2), apple maggot (Fig. 3), and Japanese beetle (Fig. 4) were slightly less abundant in the chicken and goose treatments than in the control throughout the monitoring periods. At harvest, however, only damage by plum curculio showed large differences across treatments ($F=6.31$, $p=0.03$) (Fig. 5). In the goose treatment, a mean of 61% of the fruit had plum curculio damage, compared with 78% in the control ($p=0.03$, Tukey's HSD). However, the differences between the chicken treatment and control were small ($p=0.15$, Tukey's HSD). The reduction in plum curculio damage in the goose treatment increased the proportion of pest-free fruit in that treatment ($p=0.05$, Tukey's HSD) (Fig. 5). The control had a mean of 9% pest-free fruit, compared with 21% in the goose treatment. The chicken treatment had an intermediate level of pest-free fruit but differed only slightly from the control. Damage by codling moth and tarnished plant bug was low compared with other pests, and did not differ among the treatments. (Pheromone disruption for codling moth was used in 1994.)

Potato yield was much higher in the goose treatment than in the chicken treatment and control ($F=11.7$, $p=0.009$) (Fig. 6). The mean tuber weight in the goose treatment was 5860 kg/ha (equivalent to 14122 kg/ha in monoculture). Interestingly, Colorado potato beetle was most abundant in the goose treatment (Fig. 7),

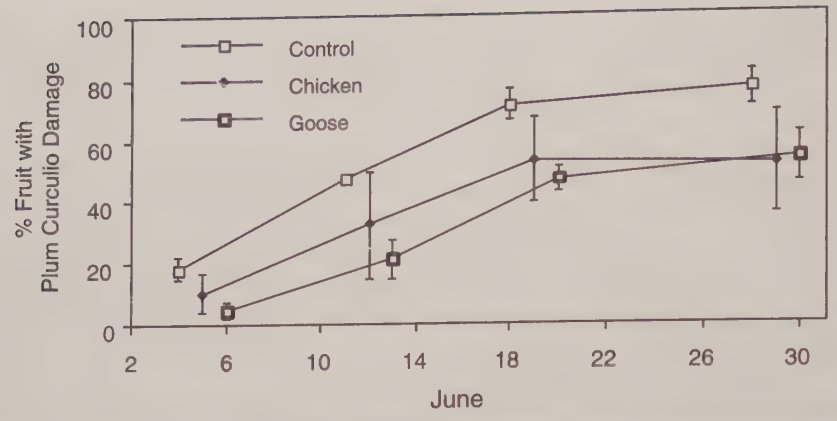

Figure 2. Cumulative percentage of apples damaged by plum curculio in the control, chicken, and goose treatments, based on visual monitoring during June, 1994 (mean ± SEM).

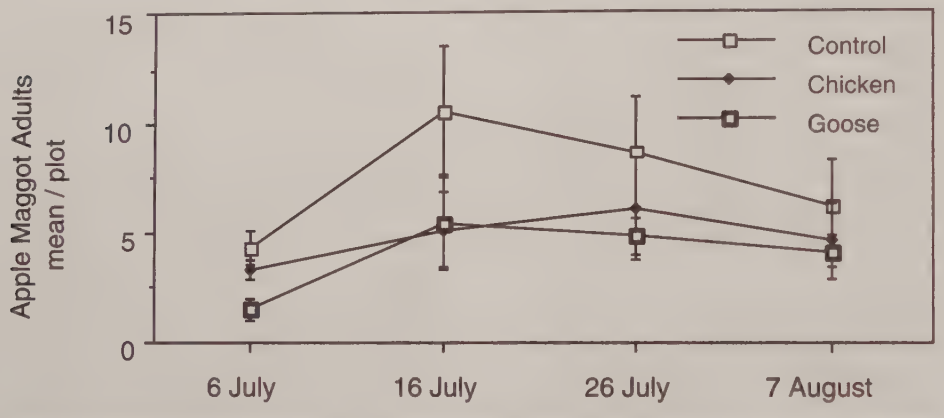

Figure 3. Apple maggot abundance in the control, chicken, and goose treatments, based on the number of adults caught on four red spheres per plot in 1994 (mean ± SEM).

Figure 4. Japanese beetle abundance in the control, chicken, and goose treatments, based on direct counts on the four sampling trees in 1994 (mean ± SEM).

the only treatment that displayed clear generational peaks of Colorado potato beetle larvae and adults. This apparent contradiction between pest abundance and yield can be explained by data on weed and potato growth (Fig. 8). Potato plants in the goose treatment had a clear advantage over weeds, which were maintained at less than 10% ground cover throughout the season by goose grazing. Consequently, potato growth rate after emergence was much greater than in the chicken treatment and control (Fig. 8). At the time the Colorado potato beetle larvae emerged (40 days after planting), potato plants in the goose treatment were more than four times larger than those of the other treatments. Large potato plants and a low abundance of weeds both increase the population of Colorado potato beetle (Horton and Capinera, 1987).

Performance of an integrated bird system

Apple yields in 1995 were extremely low in both treatments because of biennial yield cycling. Mean fruit weights at harvest for the bird treatment and control were 7.6 and 5.5 kg per tree, respectively. The weight of apple drops as a fraction of total fruit produced averaged 28% for 'Redfree' and 18% for all sampling trees, but were similar in the two treatments. As in 1994, plum curculio damage was most common. However, codling moth damage increased dramatically and was the second most common type of fruit injury (Fig. 9). Apple maggot abundance (Fig. 10) and damage (Fig. 9) were similar between treatments. Plum curculio abundance was not measured during the season. However, damage was somewhat lower in the bird treatment compared with the control ($t=2.46$, $p=0.07$) (Fig. 9). Again, this resulted in a slightly greater proportion of pest-free fruit ($t=2.64$, $p=0.06$). Although Japanese beetle was consistently less abundant in the bird treatment than in the control (Fig. 11), the proportion of damaged fruit did not differ between the treatments.

Potato yields in this experiment were very low because of a disease infestation (probably early blight, caused by *Alternaria solani)*. This was not surprising, because this was the third year that this soil was in potatoes. The patterns of Colorado potato beetle abundance were similar to those observed in 1994. A clear peak in larval abundance occurred in the bird treatment in late June, approximately 50 days after planting (Fig. 12). Considerable variation between plots is evident in the large standard errors of the means. Adult abundance was greatest in mid-July and peaked in both treatments approximately 75 to 80 days after planting (Fig. 12).

Weed growth was considerably greater in the control than in the bird treatment at the time the potato plants emerged (Fig. 13). This difference was accounted for by substantial reductions in orchard grass, Kentucky bluegrass, common chickweed *(Stellaria media),* and common plantain *(Plantago major)* (Table 1). This resulted in greater potato growth in the bird treatment,

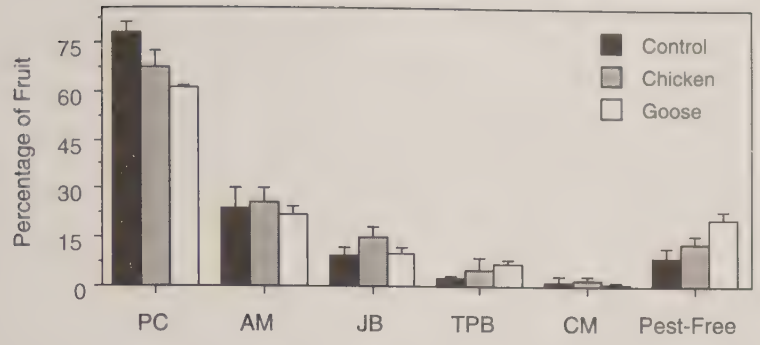

Figure 5. Percentage of harvested fruit damaged by insects (PC=plum curculio, AM=apple maggot, JB=Japanese beetle, TPB=tarnished plant bug, CM=codling moth) and undamaged (Pest-Free) in 1994 (mean ± SEM). Results of Tukey's HSD test for PC and Pest-Free comparisons between the goose treatment and control are p=0.03 and p=0.05, respectively.

Figure 6. Potato tuber yields (kg/ha) based on sampling 6 m of row in 1994 (mean ± SEM). Tuber yield was substantially greater in the plots weeded by geese compared to the plots of the control and chicken treatment (F=11.7, p=0.009)

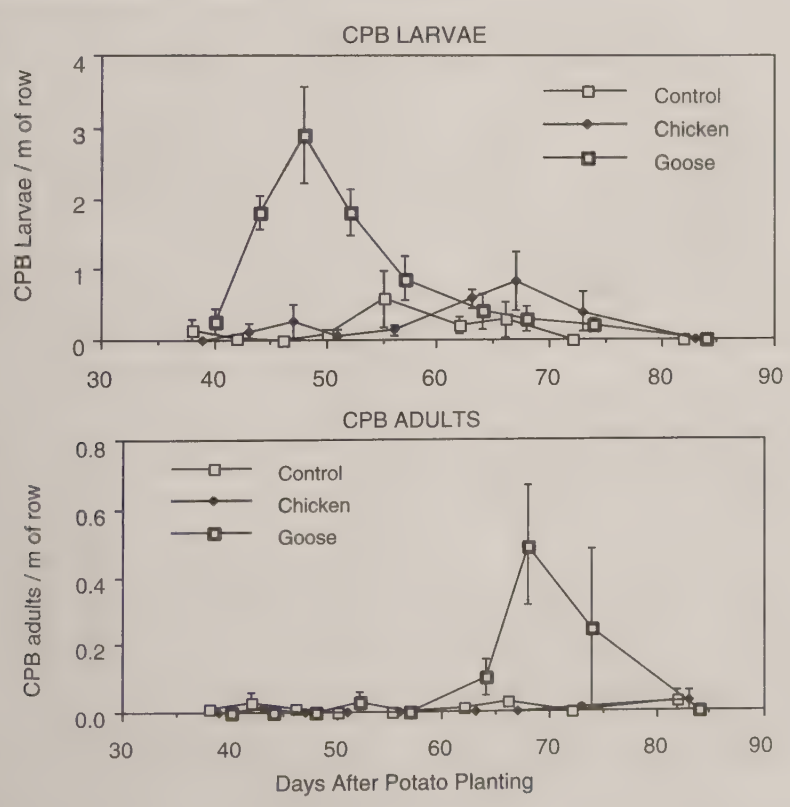

Figure 7. Colorado potato beetle (CPB) larval and adult population dynamics in the control, chicken, and goose treatments in 1994 (mean ± SEM).

especially during the first several weeks after plant emergence (Fig. 13). Although the potato plants in the bird treatment were consistently larger than those of the control for the first 70 days after planting, yield samples taken 92 days after planting showed little difference (t=1.51, p=0.21). Mean tuber weights for the bird treatment and control were, respectively, 1341 and 874 kg per ha of intercropped orchard.

Free-range chicken diet analysis

Chicken crop dissections showed that the birds fed on many different insects and other invertebrates and that the diet changed considerably over the season. We identified a total of 33 food items. However, only 11 were found in both samplings (Table 2). In June, the most common foods were ants, muscoid flies, dung beetles, earthworms, ground beetles, grass, and weed seeds. In July, the diet shifted to include fewer predators, parasitoids and detritivores, and more herbivores. The most common foods found in July were Japanese beetles, shield-backed bugs, flea beetles, shining leaf beetles, muscoid flies, ants, and grass. Japanese beetle was the most common food in the July sampling: 75% of the chicken digestive crops contained this pest. Other potential fruit and vegetable pests found in the diet included tarnished plant bugs, flea beetles, leafhoppers, wireworms, and slugs.

Discussion

The purpose of this study was to evaluate experimentally the effectiveness of free-range, domestic chickens and geese as insect pest and weed control agents in an intensively managed and integrated horticultural production system. The results support some findings of the study by Clark et al. (1995) and clearly show the potential of geese as weed control agents. In 1994, weeding by geese resulted in much higher potato tuber yields than in the unweeded control. The patterns in weed control and potato growth were similar in 1995. However, disease severely affected potato plants and tuber growth in both treatments, and yield differences were small.

An unexpected finding was the reduction in plum curculio damage with free-ranging geese. A possible explanation is that removal of vegetation by the geese reduced

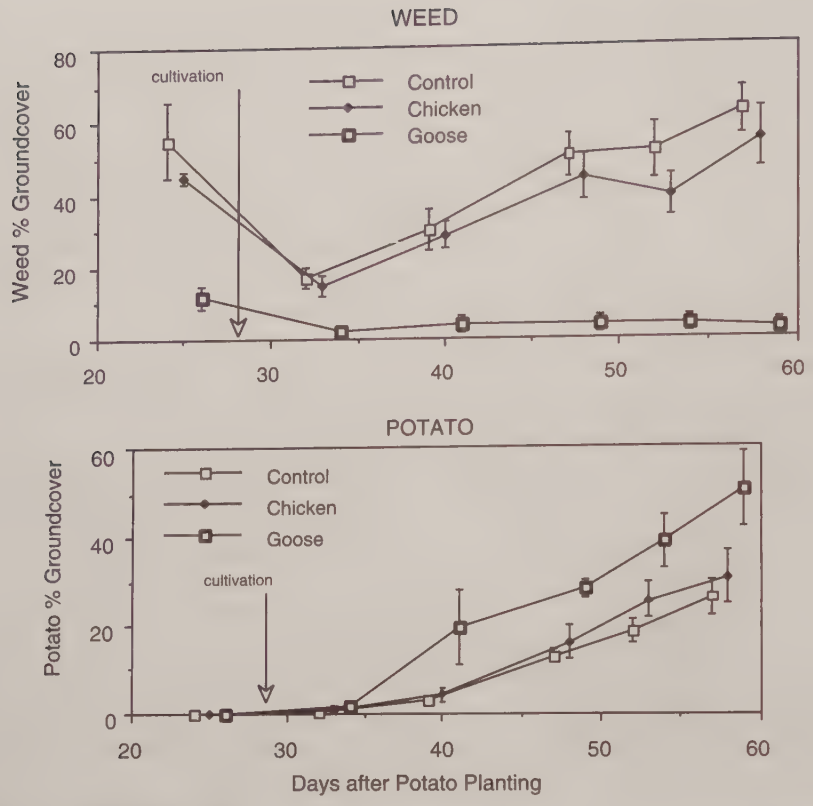

Figure 8. Percentage ground cover of weeds and potatoes in the control, chicken, and goose treatments in 1994 (mean ± SEM).

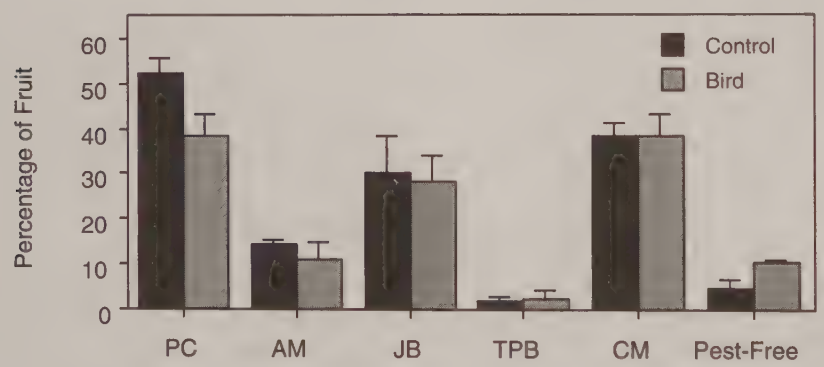

Figure 9. Percentage of harvested fruit damaged by insects (PC=plum curculio, AM=apple maggot, JB=Japanese beetle, TPB=tarnished plant bug, CM=codling moth) and undamaged (Pest-Free) in 1995 (mean ± SEM). PC damage was greater in the control (t=2.46, p=0.07), while percentage of Pest-Free fruit was greater in the bird treatment (t=2.64, p=0.06).

humidity on the soil surface, which consequently reduced plum curculio activity (Racette et al., 1992; Chouinard et al., 1993). While the observed differences in damage in 1994 undoubtedly resulted from the effects of geese, the cause of the patterns in 1995 can only be surmised. This is because the geese were removed and the chickens introduced when plum curculio usually is active. Plum curculio oviposition scars already were apparent on many fruits at the time of chicken introduction. Furthermore, plum curculio was not found in any of the digestive crops of chickens collected in June. Thus, there is no evidence that chicken predation was responsible for the reduction in fruit damage by plum curculio.

Another unexpected effect of the geese was the increase in Colorado potato beetle abundance. The larger potato plants in the weedless environment produced with weeder geese provided an ideal habitat for Colorado potato beetle (Horton and Capinera, 1987; Hare, 1990). Nonetheless, in this study Colorado potato beetle abundance appeared unimportant in influencing yields. The lack of effect from this pest was most likely because of its low population density and late arrival relative to the planting date (Zehnder and Evanylo, 1989).

The possibility of weeder geese selecting for unpalatable weeds in agroecosystems was discussed by Wurtz (1995). In her study of weeder geese in spruce seedling plots the abundance of unpalatable weeds increased by 25 times after two years. Our observations during weeding operations in late June 1995 showed that curly dock and daisy fleabane dominated in areas weeded by geese. These two species were clearly unpalatable and therefore were favored by the removal of palatable species. These observations support Wurtz's assertion that the use of geese should be integrated with other weed management methods to prevent selection for unpalatable weeds.

Chickens provided no clear crop protection benefits in 1994 or 1995. Although some insect pests were reduced in both years, no differences in pest damage or crop yield resulted. Indirect sampling of plum curculio in June 1994 showed a small reduction in activity, but only small differences in fruit damage were found at harvest. Similar differences in abundance patterns were observed for apple maggot in 1994, but no difference in fruit damage.

In 1994 and 1995 Japanese beetle was consistently less abundant in the treatments with chickens than in the control, except on the last sampling date in 1994 (5 August). Furthermore, in the analysis of chicken digestive crops Japanese beetle was the most common food item found in mid-July. Nevertheless, we found no differences in apple fruit damage by this pest. There are several possible explanations for these results. The small size of the plots compared with the general mobility of this insect may have allowed it to colonize available trees rapidly during the few weeks between chicken removal and apple harvest. Furthermore, fruit that was heavily damaged by Japanese beetle tended to drop from the trees before harvest; as a result, we may have underestimated damage in the control plots. Finally, some damage from wasps probably was

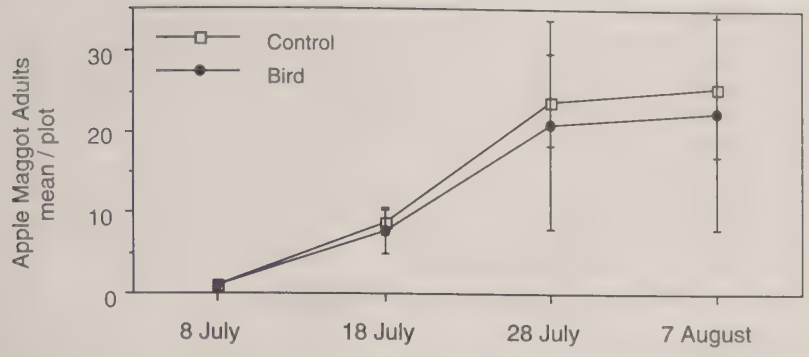

Figure 10. Apple maggot abundance based on the number of adults caught on four red spheres per plot in 1995 in the control and bird treatment (mean ± SEM).

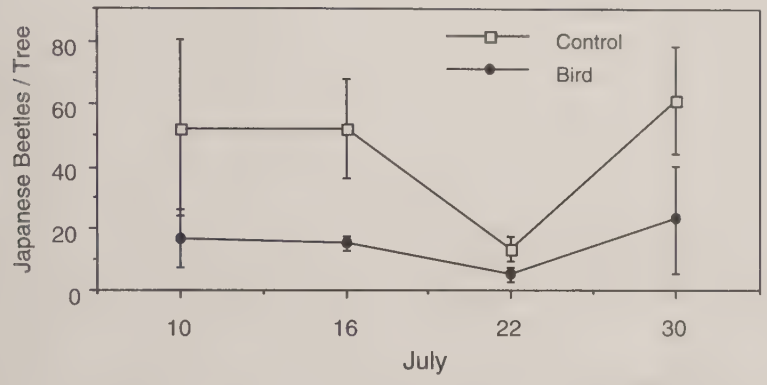

Figure 11. Japanese beetle abundance based on direct counts on the sampling trees in 1994 (mean ± SEM).

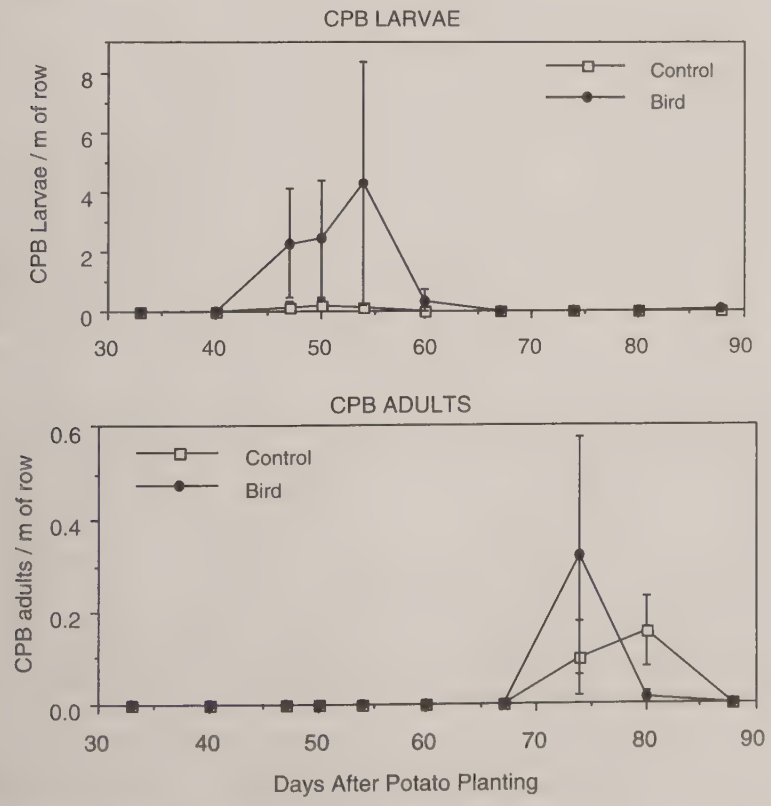

Figure 12. Colorado potato beetle (CPB) larval and adult population dynamics in the control and bird treatment in 1995 (mean ± SEM).

counted as damage from Japanese beetle. Both insects chew into the fruit; when we could not differentiate their damage, we assumed it was due to Japanese beetle. This would have inflated the estimates of Japanese beetle damage in all treatments, assuming wasp damage was not affected by treatments. Although chickens showed no clear benefits in this study, the results suggest they still may be useful as part of an integrated approach for Japanese beetle management. It is possible that a higher chicken density and the use of lures to draw the beetles within range of the birds could be used to control this pest without pesticides in apple or other susceptible crops. Other options may include using movable, floorless chicken cages, sometimes called "chicken tractors", to remove or reduce apple drops on the orchard floor.

Although chickens have been observed to feed on Colorado potato beetle in the field (Clark et al., 1995), there was no clear evidence of this from the observed population dynamics or chicken diet analysis in this study. In 1994, Colorado potato beetle abundance patterns in the chicken treatment mirrored the control primarily because of similar weed and potato growth patterns. Thus, the confounding effects of weed populations prevented an adequate assessment of chicken predation. Similarly, in 1995 weed growth in the two treatments differed considerably, especially in the early part of the season (Fig. 13), and prevented the assessment of chicken predation.

Interestingly, fewer Colorado potato beetles survived between the peaks in larval and adult abundance in the treatment with chickens compared with the control in 1995. While the mean proportion of larvae surviving to the adult stage was 73% in the control, it was only 7% in the treatment with chickens. Although greater mortality may be expected in a denser population, this large difference suggests that chickens were having an effect. Although the diet analysis offers no evidence that chickens preyed on Colorado potato beetles, the scratching and pecking typical of chicken foraging may have been enough to kill some of them, especially the larvae. Hough-Goldstein et al. (1993) found Colorado potato beetles to be unpalatable to broiler chicks but noted a high mortality rate in pecked larvae nonetheless. There are differences in foraging and feeding behaviors among chicken

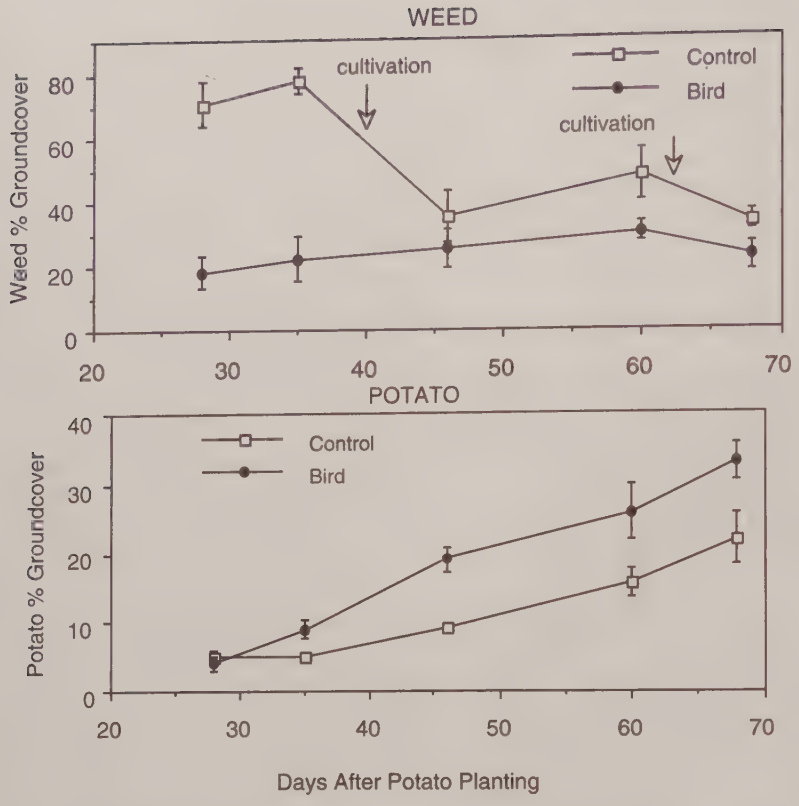

Figure 13. Percent ground cover of weeds and potatoes in the control and bird treatment (mean ± SEM).

Table 1. The abundance of common weed species based on percent ground cover estimates (mean ± SEM) taken on 30 May, 1995.

		Ground cover (%)		
Common Name	**Species Name**	**Control**	**Bird**	**p value[1]**
Orchardgrass	*Dactylis glomerata*	19.0 ± 1.2	1.3 ± 0.3	0.00
Kentucky bluegrass	*Poa pratensis*	16.7 ± 2.2	6.7 ± 1.2	0.02
Common dandelion	*Taraxacum officinale*	7.0 ± 5.0	0	0.19
Common chickweed	*Stellaria media*	6.7 ± 2.0	0.3 ± 0.3	0.04
Common plantain	*Plantago major*	5.7 ± 1.5	0	0.02
Daisy fleabane	*Erigeron annuus*	4.0 ± 1.2	2.7 ± 2.7	0.67
Curly dock	*Rumex crispus*	2.3 ± 0.9	4.7 ± 1.3	0.22
Winter cress	*Barbarea vulgaris*	0.7 ± 0.7	1.3 ± 1.2	0.52

[1] Significance level from Student's t-test.

breeds and individual chickens within breeds (M.S. Clark, personal observation; Hough-Goldstein et al., 1993). Further research is needed on how this intra- and inter-breed variability affects the usefulness of chickens to control Colorado potato beetle.

In summary, this study supports available historical and experimental evidence that domestic geese can be managed as biological weed control agents. However, on-farm evaluations are needed to address the social and economic aspects of weeder geese use. In contrast, this study offers very little evidence in support of using free-range chickens to manage insect pests or weeds. Although several insect pests, particularly Japanese beetle, were part of the chicken diet, the level of predation resulting from the bird densities in this study did not translate into a reduction in pest damage.

Acknowledgments. We thank Stephanie Clark and Peter Bingen for their exceptional field work and Sue Ellen Johnson and Dongsheng Yang for reading an earlier draft. Many thanks also to the reviewers, Mark Van Horn and Wesley Autio. Funding for this project was provided in part by the C. S. Mott Foundation and the USDA Sustainable Agriculture Research and Education Program.

References

1. Bachmann, J. 1993. Weeder geese: A practical alternative to herbicides. Kerr Center for Sustainable Agriculture. Newsletter 19:1–2.
2. Bender, J. 1994. Future Harvest: Pesticide–Free Farming. University of Nebraska Press, Lincoln.
3. Casagrande, R.A. 1987. The Colorado potato beetle: 125 years of mismanagement. Bull. Entomological Soc. Amer. 33:142–150.
4. Chouinard, G., S.B. Hill, and C. Vincent. 1993. Spring behavior of the plum curculio (Coleoptera: Curculionidae) within caged dwarf apple trees. Annals Entomological Soc. Amer. 86:333–340.
5. Clark, M.S., S.H. Gage, L.B. DeLind, and M. Lennington. 1995. Compatibility of domestic birds with a nonchemical agroecosystem. Amer. J. Alternative Agric. 10:114–121.
6. Cramer, C. 1992. Weeder geese boost berry profits $222. The New Farm 14(4):38–40.
7. Gillen, R.L., and C.J. Scifres. 1991. Selective grazing as a weed control method. In D. Pimentel and A.A. Hanson (eds). CRC Handbook of Pest Management in Agriculture. CRC Press, Boca Raton, Florida. pp. 369–376.
8. Glofcheskie, B.D., and G.A. Surgeoner. 1990. Muscovy ducks as an adjunct for the control of the house fly (Diptera: Muscidae). J. Economic Entomology 83:788–791.
9. Glofcheskie, B.D., and G.A. Surgeoner. 1993. Efficacy of muscovy ducks as an adjunct for house fly (Diptera: Muscidae) control in swine and dairy operations. J. Economic Entomology 86:1686–1692.
10. Hare, J.D. 1990. Ecology and management of Colorado potato beetle. Annual Review of Entomology 35:81–100.
11. Hoare, A.H. 1928. The English Grass Orchard and the Principles of Fruit Growing. The Riverside Press, Great Britain.
12. Horton, D.R., and J.L. Capinera. 1987. Effects of plant diversity, host density, and host size on population ecology of

Table 2. The diet components of free-range chickens in the experimental agroecosystem based on the presence/absence of items in digestive crop dissections from two sampling periods; 6-19 June (N=10) and 19 July (N=12).

Food Items			% Chicken Crops with Item	
Functional group	**Common name**	**Scientific name**	**6–19 June**	**19 July**
Herbivore	Japanese beetle	*Popillia japonica*	0	75
	tarnished plant bug	*Lygus lineolaris*	0	25
	shield-backed bug	Scutelleridae	0	50
	flea beetle	Alticinae	0	33
	shining leaf beetle	Criocerinae	20	42
	wireworm	Elateridae	0	8
	click beetle	Elateridae	0	17
	caterpillar	Lepidoptera	10	25
	leafhopper	Cicindellidae	20	25
	cicada	Cicadidae	0	8
Predator	ground beetle	Carabidae	30	0
	hover fly larvae	Syrphidae	20	0
	hister beetle	Histeridae	10	8
	soldier beetle	Cantharidae	10	0
	rove beetle	Staphylinidae	10	17
	assassin bug	Reduviidae	0	8
	wolf spider	Lycosidae	0	17
	crab spider	Thomisidae	0	8
Parasitoid	braconid wasp	Braconidae	20	0
	ichneumon wasp	Ichneumonidae	10	17
Detritivore	earthworm	Lumbricidae	30	0
	slug	Limacidae	10	0
	dung beetle	Scarabaeidae	30	8
	muscoid fly	Diptera, Muscoidea	40	33
	sap beetle	Nitidulidae	10	0
	earwig	Forficulidae	0	8
Other animals	ant	Formicidae	50	58
	hover fly	Syrphidae	0	17
	caddisfly	Trichoptera	0	8
	cuckoo wasp	Chrysididae	0	8
Plant	grass	Poaceae	30	67
	weed seeds	undetermined	30	17

the Colorado potato beetle. Environmental Entomology 16:1019–1026.

13. Hough-Goldstein, J.A., J. Greiger, D. Chang, and W. Saylor. 1993. Palatability and toxicity of the Colorado potato beetle (Coleoptera: Chrysomelidae) to domestic chickens. Annals Entomological Soc. Amer. 86:158–164.
14. Johnson, C. 1960. Management of weeder geese in commercial fields. California Agric. 14(8):5.
15. King, L.D. 1990. Soil nutrient management in the United States. In C.A. Edwards, R. Lal, P. Madden, R.H. Miller, and G. House (eds). Sustainable Agricultural Systems. Soil and Water Conservation Society, Ankeny, Iowa. pp. 89–106.
16. Loomis, R.S., and D.J. Connor. 1992. Crop Ecology: Productivity and Management in Agricultural Systems. Cambridge University Press, Cambridge, Great Britain.
17. Mayton, E.L., E.V. Smith, and D. King. 1945. Nutgrass eradication studies: IV. Use of chickens and geese in the control of nutgrass, *Cyperus rotundus* L. J. Amer. Soc. Agronomy 37:785–791.
18. Olkowski, W., S. Daar, and H. Olkowski. 1991. Common-Sense Pest Control. Taunton Press, Newtown, Connecticut.
19. Parker, C.F. 1990. Role of animals in sustainable agriculture. In C.A. Edwards, R. Lal, P. Madden, R.H. Miller, and G. House (eds). Sustainable Agricultural Systems. Soil and Water Conservation Society, Ankeny, Iowa. pp. 238–245.
20. Quaintance, A.L., and E.L. Jenne. 1912. The plum curculio. Bull. No. 103. Bureau of Entomology, U.S. Dept. of Agriculture, Washington, D.C.
21. Racette, G., G. Chouinard, C. Vincent, and S.B. Hill. 1992. Ecology and management of the plum curculio, *Conotrachelus nenuphar* (Coleoptera: Curculionidae), in apple orchards. Phytoprotection 73:85–100.
22. Salatin, J. 1991. Profit by appointment only. The New Farm 13(6):8–12.
23. Shirley, C. 1992. Put stock in orchards and woodlots. The New Farm 14(4): 35–37.
24. VABF. 1993. Proceedings of the Virginia Association of Biological Farming, New River Chapter Farmer to Farmer Conference. Floyd, Virginia.
25. Ware, A. 1995. Geese in the strawberry patch. Small Farm Today 12(3):34–36.
26. Wurtz, T.L. 1995. Domestic geese: Biological weed control in an agricultural setting. Ecological Applications 5:570–578.
27. Zehnder, G.W., and G.K. Evanylo. 1989. Influence of extent and timing of Colorado potato beetle defoliation on potato tuber production in eastern Virginia. J. Economic Entomology 82:948–953.

Erratum

In "The compatibility of domestic birds with a nonchemical agroecosystem," by Clark et al. (*AIAA* Vol. 10, No. 3, pp. 114–121), the statistical significance levels in Figs. 6 through 8 were incorrect; in all figures, *, **, and *** indicate $p<.10$, $p<.05$, and $p<.025$, respectively.

Gray World, Green Heart: Technology, Nature, and the Sustainable Landscape. Robert L. Thayer, Jr. 1994. John Wiley & Sons, 605 Third Ave., New York, NY 10158. $44.95, hardcover. 352 pp.

Professor Thayer has produced a book about ordinary people and what they see in their landscapes. In *Gray World, Green Heart*, he describes "their love of nature and land; their hopes, dreams, frustrations, actions and reactions to technology as it molds and influences their personal, tangible worlds. . . . It is about the opposition between nature and technology in our everyday lives and surroundings, and the increasing uneasiness with which we confront this opposition" (p. xiii). He has created a masterpiece in contrast, one we should read before committing even more resources for construction of houses and roads and pursuit of short-term creature comforts and enjoyment.

It is the best of times and the worst of times, as we confront the challenge of applying new technologies to meet human wants and needs. Thayer illustrates one extreme with the hyper-reality of the Mirage Hotel Casino Volcano in Las Vegas, an active mountain with a two-minute explosive cycle every 15 minutes from dark until 1 AM: "The spray plume enlarges . . . and soon is accompanied by brilliant flares of natural gas, . . . eventually engulfing the entire 'mountain' top, . . . climaxing in stabbing ridges of flame which emerge from the shallow water pond as if fissures or shafts of molten rock. . . . It is all over in two minutes" (p. 151). Is this entertainment sustainable, or even necessary? One must question if the world is a better place for the use of this technology.

In contrast, the new Arcata Marsh in northern California incorporates the latest in waste engineering in a combination of a wastewater treatment wetland, ponds for wildlife, and aquaculture. In this process, "waste enters the facility, . . . solids are eliminated and the wastewater is clarified, . . . chlorinated, dechlorinated, and fed through a succession of bulrush ponds into the secondary oxidizing lagoons, after which it passes into an additional set of ponds and wildlife enhancement marshes which fix much of the nitrogen in the food chains of typical bay marsh ecosystems. . . . Tertiary water passes through an additional set of ponds and is mixed with sea water, in which silver salmon, cutthroat trout, and sturgeon are raised" (p. 156). Here is an application of technology that solves a current human dilemma, enhances the environment, and produces food. I visited this site in summer 1995; it is truly a model for the future.

Typical of Thayer's approach to looking at today's human attempts to modify the landscape, this comparison is described in an articulate and meaningful way:

> The Arcata Marsh offers a starkly contrasting alternative to places like the Mirage "Volcano." The marsh is a manifestation of technology where a symbiotic process, carefully developed out of concern for the larger natural community of birds, fish, microorganisms, and humans, sets a conspicuous and sustainable example for community development. It brings the essential human/nature/technology interaction to the visible surface, manipulating it in such a way that waste becomes natural resource. Salmon, trout, and waterfowl thrive in a wetland environment where [human] residents jog, watch birds, or picnic. (p. 157)

In early chapters, Thayer briefly outlines a history of human interactions with land and the environment, and the increasing distance we have established from the natural world. Our love of technology is illustrated by "current residential landscapes dominated by house, driveway, and garage" and streets to provide automobile access to dwellings and communities. We place a green facade over this urban landscape, and hide behind it a complex technological support system full of gadgets and requiring vast amounts of fossil fuels to sustain. At the same time, our guilt about technology is illustrated by covers over air conditioners, underground power and telephone lines, and enclosures for garbage cans.

Once adopted, technologies can influence our life directions, and some decisions seem irreversible. Thayer suggests that the products we own define who we are; we become what we own. He points out that our ability to invent new gadgets and technologies far exceeds our ability to evaluate the impacts of these advances. He describes several cases where the philosophical dilemmas of love of technology and guilt about its consequences come to the fore. At one point, the U.S. is described as a "technological theme park" (p. 169). Thayer's description of U.S. personal belongings brings to mind the recent Sierra Club book *Material World*, a photographic and tabular comparison of U.S. families with those of other countries.

In the last section, Thayer describes the potential of sustainable landscapes as solutions to these dilemmas. The sustainable landscape is defined as "a physical place where human communities, resource uses, and the carrying capacity of surrounding ecosystems can all be perpetually maintained" (p. 235). He outlines the components of such systems, with reduced rates of consumption, closing of resource loops, and efficient recycling of all possible resources. He talks about the connectedness of elements in natural systems and the potential to tap these principles in designing human systems in agriculture, construction, water use, and wastewater treatment. The examples take into account the need for maintaining habitats large enough for other species and the landscape linkages needed to connect them. A concluding essay describing a model small city in the year 2030 provides a vision of a future that could be created if we made that choice and had the collective will to achieve such an objective.

Gray World, Green Heart is a book about sustainable landscapes. It also is a treatise on human behavior and perceived needs, and the impacts of this behavior on the ecosystem. It offers a message about future society and the choices we need to make. For thoughtful students of agriculture, communities, rural planning and the human interface with natural ecosystems, this is a stimulating book. It would be highly useful to help undergraduates expand their thinking, and would stimulate hours of classroom discussion. I highly recommend the book for its insightful look at alternative futures, those that we create with our decisions today.

Charles Francis, Professor, Department of Agronomy, University of Nebraska, Lincoln, NE 68583.

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